

An aerial photograph of a landscape featuring a wind turbine in the foreground on a grassy hill. In the background, there is a reservoir or dammed lake, surrounded by rolling green hills and a distant town or industrial area under a clear sky.

The Second National Infrastructure Assessment

**NATIONAL
INFRASTRUCTURE
COMMISSION**

Better infrastructure for all

October 2023

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 towards the back of this report and on our website at [nic.org.uk/about/what-we-do/](https://www.nic.org.uk/about/what-we-do/). This includes a table of devolved administration responsibilities by infrastructure sector.

Members of the Commission



Sir John Armitt
(Chair)



Julia Prescott
(Deputy Chair)



Professor Sir Tim
Besley CBE



Neale Coleman
CBE



Andy Green CBE



Professor Jim
Hall FREng



Professor Sadie
Morgan OBE



Kate Willard OBE



Nick Winser CBE

Full biographies can be found towards the back of this report and on our website at [nic.org.uk/about/the-commission/](https://www.nic.org.uk/about/the-commission/)

Contents

Foreword	4
Executive summary	6
Engaging with stakeholders	22
1. The challenges ahead.....	24
2. Energy and reaching net zero	35
3. Growth across all regions.....	72
4. Improving resilience and the environment.....	104
5. Investing for the future	130
6. Making good decisions, fast	141
Appendices	
A. Fiscal and economic remit	156
B. List of recommendations	170
C. Glossary	180
D. Acknowledgements.....	191
Remit and structure of the Commission.....	195
References.....	200

Foreword

Much has changed since the first Assessment in 2018. The Covid-19 pandemic and Russia's illegal invasion of Ukraine — and their impact on the cost of living — have made life harder for many households and businesses. At the same time, we have become more aware of the perils of climate change.

The good news is that modern, reliable infrastructure can support economic growth, help tackle climate change and enhance the natural environment.



We stand at a pivotal moment in time, with the opportunity to make a major difference to this country's future. But we need to get on with it.

To deliver net zero by 2050, the UK must be a long way down the road to decarbonising electricity, transport, industry and heating by the Sixth Carbon Budget in 2035. In infrastructure terms, 12 years is not a long time. Alongside this there is pressing need to improve productivity and fix decades of economic disparity between regions.

These goals require clarity and consistency of policy and regulation alongside an improved planning system to get major infrastructure projects built on time. That's how we will attract investment and action from the private sector.

Stable public funding will be also needed, particularly to help households with the upfront costs of an energy transition that will lead to long term benefits and cheaper bills.

This Assessment includes probably the most comprehensive assessment yet of the infrastructure costs associated with supporting regional growth and reaching net zero.

The public pay for infrastructure as taxpayers and bill payers — and so we must be open with them about the costs as well as the benefits.

While there's no doubt that the Commission is recommending significant changes to upgrade the country's infrastructure, they have all been costed in line with government's guideline for public investment. What's more, making these investments now should lead to permanently lower infrastructure costs for households.

In preparing this Assessment, we have consulted and travelled widely, meeting with the public, industry, academics, local and national government.

This has informed a carefully considered view of how infrastructure can support a more productive, cleaner, and fairer economy.

These objectives are shared across the political spectrum, and society more widely. We have aimed to set out a bold but achievable package of actions to help meet these goals, which we hope secure similarly broad support.

The hardest part is of course turning policy into delivery on the ground. People often talk about infrastructure as the backbone of our economy: what our infrastructure needs now is the collective mettle to turn commitments into action that will reap rewards for decades to come.

Producing a report of this breadth and depth has required a huge amount of work by the Commission's secretariat, to whom all the Commissioners express their thanks. We would also like to thank everyone else who has contributed to our work over the last two years, and we look forward to working with you as we encourage the adoption of our recommendations.

Sir John Armitt, Chair

Executive summary

The UK can have a low carbon and resilient economy with infrastructure that supports economic growth and protects the natural environment. Delivering such an infrastructure system will require government to make bold decisions, plan for the long term and support households through the transition. The UK needs to invest in its future — and now is the time to act.

In the five years since the first National Infrastructure Assessment, government has worked to increase the share of electricity generated by renewables, set up the UK Infrastructure Bank, devolve transport funding to major city regions, and provide industry with the direction to rapidly build gigabit capable broadband networks.

But there is more to be done to address significant deficiencies in the UK's economic infrastructure and ensure it can meet the challenges ahead. For the first time, households face changes to reduce emissions, get off gas and oil and ensure energy security. Not only will households switch to electric vehicles, but they will need to swap their gas boilers for cleaner, more efficient heat pumps. While these technologies should roughly halve energy costs for households in the coming decades, the transition must be carefully managed to ensure the public are supported with the upfront costs and government protects the living standards of those least able to pay.

There would be significant benefits from improving connectivity. For transport networks, investment is required to facilitate sustainable trips within and between English cities. For digital networks, government should secure nationwide coverage of gigabit broadband and 5G services, and ensure the specific telecoms needs of infrastructure services are met. Increasing the quality of transport and digital networks will be necessary, although not sufficient, to reduce long standing disparities in economic outcomes and quality of life.

At the same time, all infrastructure systems should be more resilient and protect the environment. The UK's infrastructure has proved fairly resilient over recent decades, but faces increasing exposure to shocks, including from the environment. Better maintenance and renewal of the existing asset base will be essential, as will building new infrastructure to protect households and businesses from flooding and drought.

Delivering low carbon and resilient infrastructure will require a significant increase in overall investment. The costs as well as the benefits of transforming the UK's infrastructure will be borne by the public as taxpayers and billpayers. But making these investments will help lower costs for households and keep them lower in the longer term. These upfront investments will be paid for by consumers in their bills over the coming decades, not all at once.

While upgrading the country's infrastructure is a major task, it is achievable, provided government makes decisions and commits to them for the long term, removes barriers to progress and supports people through the transition in a way that is both affordable and fair. This Assessment sets out recommendations to help government do so.

The core recommendations the Commission is making to government include:

- **adding low carbon, flexible technologies to the electricity system to ensure supply remains reliable, and creating a new strategic energy reserve to boost Great Britain's economic security**
- **taking a clear decision that electrification is the only viable option for decarbonising buildings at scale, getting the UK back on track to meet its climate targets and lowering energy bills by fully covering the costs of installing a heat pump for lower income households and offering £7,000 support to all others**
- **investing in public transport upgrades in England's largest regional cities to unlock economic growth, improving underperforming parts of the national road network and developing a new comprehensive and long term rail plan which will bring productivity benefits to city regions across the North and the Midlands**
- **ensuring gigabit capable broadband is available nationwide by 2030 and supporting the market to roll out new 5G services**
- **preparing for a drier future by putting plans in place to deliver additional water supply infrastructure and reduce leakage, while also reducing water demand**
- **setting long term measurable targets and ensuring funded plans are in place to significantly reduce the number of properties that are at risk of flooding by 2055**
- **delivering a more sustainable waste system by urgently implementing reforms to meet the 65 per cent recycling target by 2035, and creating stronger incentives for investment in the recycling infrastructure that will be needed in the future.**

The National Infrastructure Assessment

The Commission is required to carry out an overall assessment of the UK's infrastructure requirements once every five years. The first Assessment was published in 2018 and has shaped many aspects of infrastructure policy, including the establishment of the UK Infrastructure Bank, increased support for renewables, committing to transition to electric vehicles, devolved budgets for local transport, deployment of gigabit capable broadband networks, and the long term direction for water resources policy.

This is the second Assessment. It covers all economic infrastructure sectors, setting out recommendations for transport, energy, water and wastewater, flood resilience, digital connectivity, and solid waste. The Assessment takes a 30 year view of the infrastructure needs within UK government competence and identifies the policies and funding to meet them.

The Assessment is guided by the Commission's objectives to support sustainable economic growth across all regions of the UK, improve competitiveness, improve quality of life, support climate resilience and transition to net zero carbon emissions by 2050. Government has given the Commission a long term funding envelope for its recommendations (the 'fiscal remit'). Where infrastructure is financed by the private sector, and the costs of any recommendations will ultimately be met by consumers, the Commission is also required to provide a transparent assessment of the overall impact on household costs (the 'economic remit').

The challenges ahead

While infrastructure performs well in some areas, in others there are significant deficiencies that are holding the UK back. There has been under investment in transport systems in regional English cities, no major water resource reservoirs have been built in England in the last 30 years, too many properties are at risk of flooding, and recycling rates have not increased in a decade. This situation must improve.

Infrastructure is pivotal to addressing some of the biggest strategic challenges facing the UK, namely decarbonising the economy, boosting economic growth, and improving resilience and the environment. Proactively tackling these challenges provides an opportunity to bring major benefits to the UK. Government, regulators and industry must act urgently, with policies of sufficient scale to move the dial and enable rapid delivery on the ground. Doing so will require significant investment in economic infrastructure and the transition should be affordable and fair. This is a big task. But it is achievable. The UK has made major changes to infrastructure before — from building the electricity ‘supergrid’ in the 1950s to constructing the strategic road network in the 1960s and 70s — and can do so again.

Energy and net zero

Phasing out the use of fossil fuels to generate electricity, heat homes and power vehicles will reduce greenhouse gas emissions, and is essential for the UK to meet its legally binding climate targets. Action is now urgent with only 12 years left to meet the Sixth Carbon Budget. This shift will also bring significant economic benefits. Shocks to oil and gas prices will have a much smaller impact on the cost of living. If the UK can move fast, some businesses should be able to become leaders in new low carbon technologies. And, in the longer term, electrifying the energy system should lower energy costs for households and businesses, boosting productivity.

Supporting growth across regions

The UK must address its persistent slow economic growth and entrenched regional inequalities. Since the mid 2000s, UK productivity has fallen further behind comparator countries such as France, Germany, and the United States. In addition, the UK has long standing and self reinforcing variations in economic outcomes between and within regions. One of the reasons for this poor economic performance in recent years is low levels of investment in the UK economy compared to international peers: in the 40 years to 2019, investment in the UK averaged around 19 per cent of GDP, the lowest in the G7.

Better transport and digital networks can support economic growth in both high performing and underperforming places. Investment in transport networks can enable sustainable trips within and between cities — the main engines of economic growth. Better connections can boost productivity in cities through increasing access to high skilled labour, attracting new investment and firms, and capitalising on agglomeration benefits. Better connections between cities facilitates more efficient trade in goods and services. And delivering nationwide coverage of gigabit broadband and new 5G services can stimulate innovation and help to improve productivity in some sectors.

Improving resilience and the environment

It is important that infrastructure is both resilient to external events and protects the natural environment. Resilience shocks are infrequent and future benefits uncertain but the cost of intervention is concrete and immediate. Therefore, both the public and private sector are likely to under invest in resilience unless government acts to set expectations through service standards and ensures resilience is properly valued. Meanwhile, biodiversity is at risk and the stock of natural capital is in decline. With appropriate intervention, infrastructure can help solve, rather than exacerbate, this challenge.

This Assessment sets out recommendations to meet these strategic challenges and make the most of the opportunities they present. The Commission has used five policy principles to guide its recommendations:

- **Removing barriers and accelerating decisions:** Currently there are too many barriers that slow down infrastructure decision making and delivery. These make the UK a less attractive place to invest. Policy must change to facilitate faster progress.
- **Taking long term decisions and demonstrating staying power:** Repeatedly changing policy creates uncertainty for infrastructure operators and investors, which deters investment. It also slows the development of supply chains, driving up costs.
- **Pace, not perfection:** Ambitious goals must be backed up by bold policies and effective implementation. To make the rapid progress required, options must be closed down where the risk of delay is greater than the risk of making a suboptimal decision.
- **Furthering devolution:** Decisions made at the local level are better able to reflect local preferences, circumstances, and information. Implementation is often most effective when undertaken at the local level. As such, when done well, devolution is associated with productivity benefits and reduced regional differences. Historically, the UK has struck the wrong balance between risk sharing nationally and local autonomy on spending and taxation.
- **Adaptive planning:** There is inevitable uncertainty associated with long term infrastructure policy making. Decision makers must not be continually buffeted by this uncertainty, nor ignore it. In this Assessment, the Commission sets out a portfolio of policies that use adaptive pathways to effectively navigate uncertainty.

However, better policy alone is not enough to create low carbon, connected and resilient infrastructure. The Commission's recommendations must be accompanied by effective implementation to rapidly deliver projects on the ground. This is the only way in which high quality infrastructure services — from effective, reliable and accessible transport to safe and secure energy — will be provided to people across the country, enhancing living standards for decades to come.

Energy and net zero

To tackle climate change and ensure energy security, the UK should move away from its reliance on fossil fuels. Currently around 80 per cent of the energy demand is met by fossil fuels, primarily from fossil fuel based electricity generation, natural gas boilers for heating homes and businesses, petrol and diesel cars and vans, and fossil fuels powering industry.

The solution is to replace these fossil fuels with low cost, reliable, low carbon electricity. This will require a fundamental change in the country's energy infrastructure. Over the next 30 years the country will need:

- a larger electricity system running mostly from renewable power sources like wind and solar
- heat pumps and networks to replace gas boilers in homes and businesses
- cars and vans fuelled by clean electricity and charging infrastructure to replace petrol stations
- industry running on electricity where possible, but, where it is not, new infrastructure to supply clean hydrogen, or capture and transport the carbon emitted from burning fossil fuels to underground stores.

Moving to an electrified energy system should create cheaper, less price volatile energy in the long term. An energy system running on electricity, rather than fossil fuels, is more capital intensive and so insulated from fuel price changes. This should lower costs for households and businesses and provide more certainty over future prices. However, there will be significant upfront costs from creating the new capital assets needed and government should provide support during the transition, especially to households on lower incomes.

There have already been major steps forward. In 2022, electricity generation produced 75 per cent less emissions than it did in 1990 as renewables replaced fossil fuel powered generation. The share of new car sales that are battery electric has increased from less than one per cent in 2015 to around 16 per cent in 2022.

While there is still a long way to go in creating a secure net zero energy system, it is achievable with the right policies and a relentless focus on delivery. The UK has transformed its energy system many times before. In the 1960s and 70s, all properties connected to the gas network were converted from town gas to natural gas in just ten years. In the 1990s 'dash for gas', the UK built almost 40 gas power stations, and more recently since 2010 the UK has deployed over 13 GW of offshore wind and now has the second largest offshore wind fleet in the world.

Building a secure, low carbon electricity system

By 2035, the UK needs a reliable electricity system running mostly on renewable power. Government should accelerate the deployment of offshore wind, onshore wind and solar power. These technologies should be complemented by more flexible technologies that can generate if the sun isn't shining or the wind isn't blowing. Government should support the market to deploy electricity storage and demand side response (tools and incentives to

reduce or reschedule energy usage at times of peak demand). At the same time, it's critical that government establishes effective business models that incentivise investment in large scale hydrogen and gas with carbon capture and storage power stations that can provide electricity even during extended calm or cloudy periods. More demand for electricity means more transmission and distribution cables are required. Investment in electricity networks has not kept up with demand and therefore connections to the network are being delayed. The scale and speed of infrastructure deployment requires transformational change to planning, regulation and governance of both the transmission and distribution networks.

The electricity system will become even more important as the rest of the economy electrifies and so needs to be underpinned by a new strategic energy reserve. The energy system has proven to be vulnerable to price shocks such as that caused by Russia's illegal invasion of Ukraine. Part of the reason it was so exposed was because it did not have adequate gas reserves that could be used to mitigate the impact of the shock. Government should establish a reserve of energy that can be released into the market to generate electricity in order to mitigate the effect of price shocks in the future.

Switching to electrified heat

Gas boilers, which currently heat around 88 per cent of English buildings, need to be phased out and replaced by heat pumps. Around eight million additional buildings will need to switch to low carbon heating by 2035, and all buildings by 2050. Heat pumps and heat networks are the solution. They are highly efficient, available now and being deployed rapidly in other countries. The Commission's analysis demonstrates that there is no public policy case for hydrogen to be used to heat individual buildings. It should be ruled out as an option to enable an exclusive focus on switching to electrified heat.

Kick starting the market for heat pumps and heat networks will require urgent action and implementation from government, including a number of one off investments:

- committing £1.5 to £4.5 billion per year to improve energy efficiency and install heat pumps across the public sector estate and social housing that will help boost supply chains
- closing the gap with the lifetime cost of gas boilers by providing an initial upfront subsidy of £7,000 to households installing heat pumps or connecting to heat networks, alongside access to zero per cent financing, backed by government, for the additional cost
- committing £1 to £4 billion per year to cover the full cost of heat pump installations and support energy efficiency improvements for households on lower incomes that will be unlikely to be able to fund the costs themselves
- taking policy costs off electricity bills and ensuring the cost of running a heat pump is lower than the cost of running a gas boiler.

Effective delivery will be supported by setting devolved long term budgets for local authorities for decarbonising the homes and buildings they are responsible for. Collaboration between energy suppliers and local authorities will also ensure energy efficiency improvements are targeted at those most in need.

Rolling out electric vehicles

Increasing the adoption of electric vehicles will be key to decarbonising surface transport. Electric cars and vans are the future of road transport. As well as being zero emission, they are cheaper to run and create less air pollution.

But consumers will only purchase electric vehicles if they are confident they can charge them when they need to. Government should ensure there is a nationwide network of public charge points, reaching at least 300,000 chargers across the UK by 2030. These charge points must be spread across all regions of the country to support every consumer to make the switch.

New networks to support industry

Government has set stretching industrial decarbonisation targets. A comprehensive strategy is required to meet those targets and ensure the UK protects its industrial activity as buyers increasingly demand low carbon products. Decarbonising the industrial sector requires switching from fossil fuels to a mix of electricity, hydrogen and fossil fuels abated with carbon capture and storage. Industry needs clarity from government on which decarbonisation routes will be open to them and certainty on where supporting infrastructure will be available and by when.

Core networks of infrastructure to transmit and store hydrogen and carbon are essential by 2035. They will support industrial decarbonisation and provide the fuel needed to generate low carbon electricity. This carbon capture and storage system should have capacity to store at least 50MtCO₂e per year by 2035 and the core sites should cover Grangemouth and North East Scotland, Teesside, Humberside, Merseyside, the Peak District and Southampton. Similarly, the core hydrogen transmission network should connect Grangemouth and North East Scotland, Teesside, Humberside, Merseyside and South Wales.

Supporting growth across regions

Better transport and digital networks can support economic growth across regions. Cities are the main drivers of economic growth — they have the highest employment density and largest concentrations of productive businesses. But large regional English cities are less productive than comparable European cities, partly because they have worse public transport networks. Investing in transport infrastructure can help support movement within cities and enable more efficient trade of goods and services between them, in turn helping to increase productivity. Better transport networks also improve quality of life and raise living standards, by making it easier to access public services, retail, and leisure activities. There should not be a choice between improving local and inter city transport - the UK should do both if it wants to ease constraints on growth.

Travel demand patterns have changed, to some degree, following the Covid-19 pandemic, which increased the frequency of home and hybrid working. But this has not weakened the case for long term investment. The largest cities are likely to require more capacity on their public transport networks to support economic growth over the next 20 to 30 years, and that is true even if home and hybrid working remain above pre pandemic levels.

Better digital connectivity can also boost economic growth. Improving digital connectivity can lower costs for firms, enable technological changes and innovation, and provide businesses with access to a wider pool of talent for recruitment.

In both the transport and digital sectors, there are clear actions for government to take:

- investing in the maintenance and renewal of existing transport infrastructure on both a national and local level, and planning for the effects of climate change
- enabling investment in new and improved transport networks to facilitate sustainable trips within and between cities
- delivering nationwide coverage of gigabit broadband and new 5G services to stimulate innovation and improve productivity in some sectors.

Getting cities moving

England's largest cities have congested roads and inadequate public transport networks, which constrains their economic growth. The solution is better public transport, and more, safer, active travel. Public transport is much more space efficient than cars — a bus lane can carry around twice as many passengers per hour as a normal lane.

Government should invest £22 billion to improve public transport in the largest regional English cities to unlock economic growth. Birmingham, Bristol, Leeds and Manchester are important economic hubs within their wider regions but face the biggest transport capacity constraints. They should be the initial priorities for investment in mass transit systems. As cities will be the primary beneficiaries of better public transport, they should contribute to the costs. Cities should have the autonomy to fund as well as find local infrastructure solutions.

However, investment in public transport alone will not be sufficient to reduce congestion and improve capacity. Cities will also need to reduce car journeys into congested city centres, especially at peak times. Measures such as congestion charging and workplace parking levies can reduce car use, thereby freeing up room on the roads for more public transport. The sequencing of these transport changes will be important as reducing trips by car where there is no viable public transport alternative risks hindering, not supporting, growth and having negative social impacts.

More devolution and bigger local transport budgets are essential for better maintenance and continued transport enhancements across the country. This will give local authorities the freedom to identify local priorities, such as fixing potholes, zero emission buses and road improvements, and the resources to address them. Government should move away from centrally allocated funding pots for transport and, instead, implement flexible, long term, devolved budgets for all local authorities that are responsible for strategic transport. Government has made progress with the City Region Sustainable Transport Settlements and the recent 'trailblazer' deals for Greater Manchester and the West Midlands. The City Region Sustainable Transport Settlements model should now be extended beyond the Mayoral Combined Authorities, and the 'trailblazer' deals rolled out to all Mayoral Combined Authorities. London also requires a long term funding settlement to enhance its world class public transport network. Short term funding deals for Transport for London should be replaced with longer term capital settlements, sufficient to enable the enhancement and expansion of London's transport services to support housing and economic growth.

Improving national road and rail networks

National road and rail networks are essential for connecting places, and so they must be well maintained. This will likely be more expensive in the future due to climate change, ageing assets and increased demand. Maintenance of existing national road and rail networks should be prioritised.

Government had developed a long term plan to improve rail performance between cities in the North and the Midlands. The High Speed 2 line between London and Manchester via Birmingham, alongside Northern Powerhouse Rail and other changes, would have improved significantly north-south and east-west rail connectivity. This investment would also have freed up capacity on the existing rail network, enabling more local and regional services to run and providing significant increases to city centre accessibility.

The second Assessment has been undertaken on the basis of the delivery of this long term rail plan. On 4th October, government announced that High Speed 2 from Birmingham to Manchester will not go ahead and set out a new package of transport schemes. This decision leaves a major gap in the UK's rail strategy around which a number of cities have based their economic growth plans. While government has committed to reallocate the funding from cancelling the later phases of High Speed 2 to improve transport, including rail links, in the North and Midlands, it is not yet clear what the exact scope and delivery schedule is for the proposed new rail schemes. A new comprehensive, long term and fully costed plan that sets out how rail improvements will address the capacity and connectivity challenges facing city regions in the North and Midlands is needed. The Commission could support government in undertaking this work.

Alongside this, government should take forward a programme of enhancements to the road network that target underperforming sections, provide better connections between cities and facilitate trade in goods and services. It is not clear that this prioritisation happens at present – in the allocation of funding for the second Road Investment Strategy, only 22 per cent of funding allocated was in the North and the Midlands. Government should plan these enhancements on a strategic basis, aligning schemes with complementary policies that support economic growth. This should be underpinned by a national integrated strategy for interurban transport, including a pipeline of strategic improvements to the road and rail networks over the next 30 years.

Enhancing digital connectivity

Coverage of gigabit capable connectivity has improved in recent years. To ensure the UK meets the target of nationwide coverage by 2030, policy and regulation must continue to support private investment in networks and competition. Government should also finish delivering the £5 billion subsidy programme to provide coverage in the hardest to reach areas.

As the UK is still at a relatively early stage in 5G deployment, government should support a market led approach by improving the consistency of planning approvals across the country and supporting access to spectrum for localised private networks. Government should also be prepared to act fast to support deployment in uncommercial areas, should essential 5G use cases emerge. Better digital connectivity will also be vital to delivering critical functionality and strategic objectives across other infrastructure sectors. Between now and the end of 2026, government should set out plans for how the telecommunication needs of the energy, water and transport sectors will be met, including ensuring adequate access to spectrum.

Improving resilience and the environment

The UK's infrastructure has proved fairly resilient over recent decades, but faces increasing exposure to shocks, including from the environment.

Infrastructure resilience must be taken seriously across all sectors. As the impacts of climate change increase, flood risk management infrastructure will be needed to prepare for floods, and increased water supply and water demand management will be needed to prepare for droughts.

But infrastructure systems should not just be resilient to the environment, they should also support improvements in it. Infrastructure has in the past been partly responsible for negative environmental impacts. In the future infrastructure can, instead, contribute to a healthier natural environment by, for example, increasing recycling and reducing waste, using nature based solutions for drainage and wastewater treatment and taking a strategic approach to biodiversity net gain.

Improving asset management and climate resilience

Most infrastructure assets that will be operating in 2055 have already been built. Better asset maintenance and renewal is therefore critical to achieving more resilient infrastructure. To achieve this, government should publish outcome based resilience standards for infrastructure sectors by 2025 to inform future regulatory and funding settlements. Government should also require infrastructure operators to set out the costs of meeting these standards, and work with the Met Office and standards bodies to enhance the tools available to assess this.

The UK will also need new assets to adapt to a changing climate. Currently 900,000 properties have a greater than one per cent annual risk of flooding from rivers and the sea. For surface water flooding the figure is 910,000. Government should invest in enhanced flood risk management infrastructure to reduce the risk of coastal, river and surface water flooding, with clear risk reduction targets and, in the case of surface water, improved data gathering and coordinated governance at a local level.

Without action, there will also be an over 4,000 mega litre per day gap between the demand and supply of water by 2050. Government should follow a twin track approach to drought resilience, by managing demand and increasing supply. Both reducing demand, including leakage, and providing new water infrastructure will require additional investment in the upcoming sector Price Review 2024 and beyond.

Improving the environment

Alongside improving resilience, infrastructure services should reduce their impact on the environment and leave the natural world in a better condition. This means reducing the impact of wastewater on water bodies and encouraging a more circular economy in waste disposal. Government should implement without delay its planned packaging reforms. It should also widen its restriction on plastic packaging and set individual targets, with transition funding, for local authorities, to help achieve its target recycling rate of 65 per cent by 2035. Finally, government should set stronger incentives for recycling investment and phase out the use of unabated energy from waste processing.

Government should build on its commitment to biodiversity net gain by requiring sectors with the greatest opportunity — transport, water and flood risk management — to take a strategic approach to enhancing natural capital across their estate.

Investing for the future

The Commission's recommendations require an ambitious and sustained programme of policy change with clear direction. Realising the benefits will require a significant increase in overall investment in economic infrastructure. These investments are vital to the challenges ahead. Making them now should lead to lower overall costs for households and businesses for the long term.

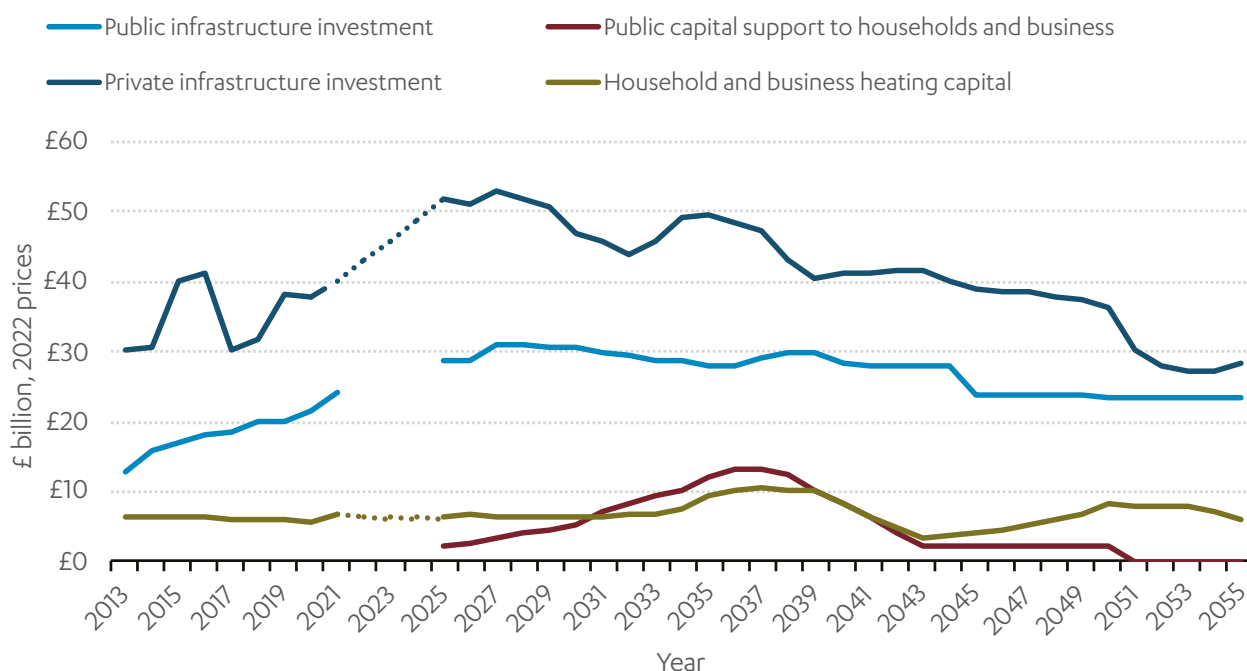
The Commission's analysis suggests that overall investment must increase from an average of around £55 billion per year over the last decade (around ten per cent of UK investment) to around £70 to 80 billion per year in the 2030s and £60 to £70 billion per year 2040s. Public sector investment will need to rise from £20 billion per year over the last decade to around £30 billion in the 2030s and 40s. At the latest spending review, government committed to increase this to around £30 billion for the years 2022-23 to 2024-35. This is a sharp rise, and government should ensure that it does get spent. In recent years one in every six pounds of planned capital expenditure has gone unspent. Private sector investment will need to increase from around £30 to 40 billion over the last decade to £40 to £50 billion in the 2030s and 2040s. The main areas for investment are:

- to reach net zero, around £20 to £35 billion per year between 2025 and 2050 of private sector investment in renewable generation capacity and flexible sources of generation, electricity networks, and hydrogen generation, storage and networks and a carbon capture and storage network
- to support growth across regions, investments including better public transport in cities and improved national road and rail connections, will total around £28 billion per year from the public sector — the balance of this investment will shift towards urban transport, increasing from around 40 per cent today to 50 per cent in the 2040s, reflecting the economic growth potential of cities
- to improve resilience and the environment, investments will total £1 to £1.5 billion per year from the public sector and £8 to £12 billion per year from the private sector over the next 30 years.

In addition, the Commission is recommending that government supports households through the energy transition to ensure it is both affordable and fair. The Commission's recommendations involve government investing £3 to 12 billion per year to support households to decarbonise their heating systems over the next 15 years. Public support will have to be complemented by household investment of a similar size (Figure 1). Critically, these costs will not be borne up front by households as the Commission is also recommending government backed zero per cent financing is put in place so this cost is spread over time.

Figure 1: Both public and private investment will stay higher than in recent years

Public and private investment in economic infrastructure from 2013 to 2055



Source: Commission analysis.

Note: Dotted lines cover the period between latest outturn data for 2021 and the start of Commission forecasts in 2025, based on a straight line interpolation. Profile of public infrastructure investment includes the sections of HS2 that will not now go ahead.

The Commission recognises the context in which it makes the case for increased investment, which is ultimately funded by households and businesses — either through taxation, bills, or the price of products purchased. Since 2019, households have faced a series of adverse shocks, most recently on cost of living. A significant proportion of the population are in fuel poverty.

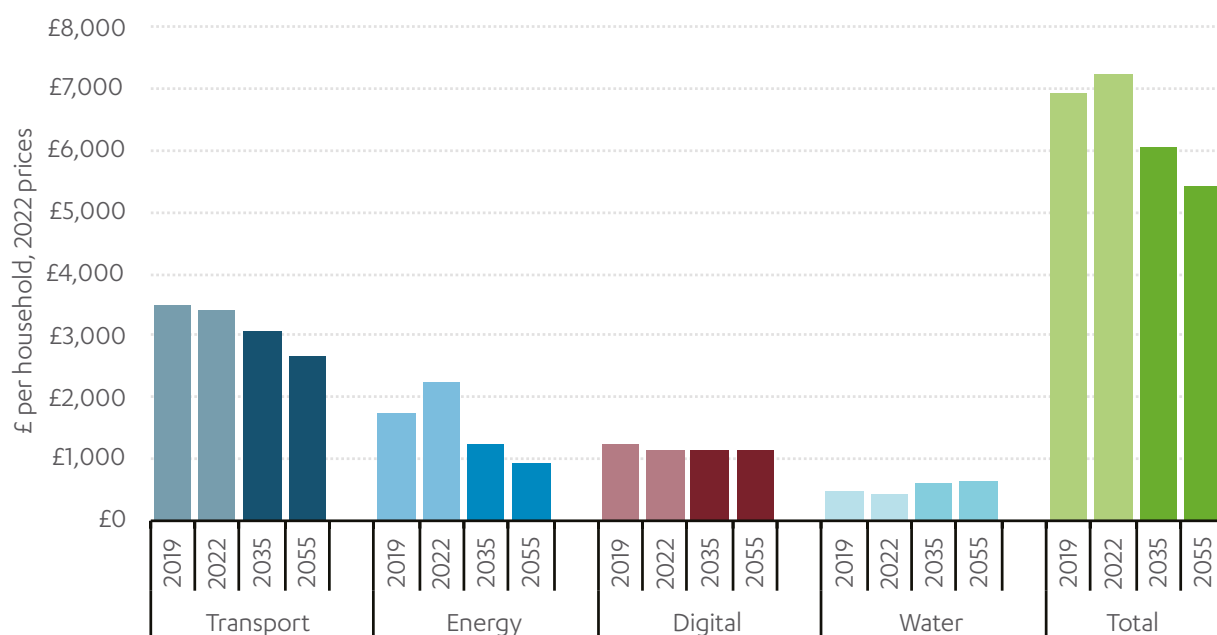
But making these investments will help lower costs for households and keep them low in the longer term. These upfront investments will be paid by consumers in their bills over the coming decades, not all at once.

In total, overall household spending on infrastructure should fall from today's £7,300 per household to around £5,500 to £6,600 by the mid 2030s. For the next few years, energy costs will largely be driven by the volatile and difficult to predict gas price. But beyond that, the key driver of lower household costs is transitioning away from fossil fuels and onto cheaper, reliable low carbon electricity. A fossil fuel based system has high operating costs. Natural gas, coal, or oil must be continually purchased and burned to generate electricity. A system running on renewables, heat pumps and electric cars will have high upfront costs that are paid for slowly over time but it is cheaper to run. Offshore wind, onshore wind and solar farms have low operating costs as they require no fuel inputs. Heat pumps and electric vehicles are much more efficient than gas boilers and petrol or diesel cars. The cheaper operating costs of a low carbon energy system more than offset the costs of paying for the new infrastructure, leading to lower household costs.

This reduction in energy costs should be much greater than the upward pressure on bills from increased investment required in the water sector to reduce both pollution and drought risk.

Figure 2: Overall household spending on infrastructure should fall by at least £1,000 from today's high levels

Household spending on infrastructure 2019 to 2055



Source: Commission analysis

Critically, it is not only the average household cost impact that is important, but also the impact on lower income households. The Commission has sought to ensure its recommendations in this Assessment, if carefully implemented, will not have a disproportionate impact on such households, by undertaking distributional analysis, engaging with experts, and commissioning social research.

Making good decisions, fast

The majority of the investment needed will come from private capital. Securing this wave of private sector investment will require better policy and decision making. There is private finance available but, to secure it, the UK must be able to attract investors based on the strength of its policy and regulatory environment and the returns available from projects.

Government must be able to make good decisions, fast. There need to be changes to planning, predictable regulatory models that allow rates of return commensurate with the level of risk, better strategic policy direction from government, increased use of competition and good infrastructure design. All this can help secure private investment, although changes to public investment decisions are also essential.

An effective planning system that enables good decisions to be made swiftly is essential for attracting investment. While the Nationally Significant Infrastructure Planning framework initially worked well, it has deteriorated in recent years — consenting timelines have slowed by 65 per cent. Government has taken some positive steps towards reform, but more is

needed, including: updates to National Policy Statements at least every five years, better use of environmental data, a meaningful and consistent approach to community benefits, integrated spatial planning, and more robust oversight and accountability at the centre of government.

The UK's system of economic regulation needs to be updated to enable the transformational change required to tackle net zero and climate resilience. It is critical that regulation maintains the confidence of both the public and the private sector. To do this, regulators must ensure that the private companies they regulate are financially sustainable. This includes considering appropriate gearing ratios and linking returns to both risk and performance. Greater consistency is required across price regulated regimes, including in how the allowed cost of capital is set.

Further action is also needed to support investment, including:

- Strategic direction from government to regulators through regular Strategic Policy Statements for each sector. These statements should set out a coherent long term vision for sectors aligned with government's policy priorities. At a time when the water and energy sectors need transformational change, not just marginal efficiency improvements, regular Strategic Policy Statements are essential for giving regulators clarity to prioritise investment, especially when it is required ahead of need.
- Enhanced use of competition, where appropriate. Investment aimed at addressing strategic challenges will be made in the context of high levels of uncertainty and rapid technological change. One way to capitalise on this opportunity for innovation is through an increased role for competition. Removing some major strategic investments from the price controls and opening them to competition will both boost innovation and give infrastructure providers confidence to deliver long term projects within a stable regulatory environment. However, competition will not be appropriate in all circumstances. In some cases, introducing competition could slow delivery in the short term or hinder the coordinated delivery of networks.
- New business models are needed to support deployment of hydrogen and carbon capture and storage networks, and new forms of flexible electricity generation. These business models must provide investors with clarity and certainty, alongside an appropriate rate of return and replicate the success of the contracts for difference model for renewable electricity generation.

Good infrastructure design provides value for people, places, and the climate while also helping projects finish on time and at lower cost. Embedding this process into the culture of delivery from the outset of projects can improve aesthetics, drive wide community engagement and maximise the benefits of the project.

Having visible and long term pipelines of investment opportunities will be necessary for the market to invest in the skills and supply chains essential to deliver the required infrastructure on time and to budget.

Effective policy and decision making are not just essential to support private sector investment, they are also critical for public sector investment too. Major infrastructure projects should be given separate budgets for their lifetime. The largest projects should be given their own 'departmental style' settlements with explicit contingency budgets to ensure that cost or time

overruns don't prevent other smaller projects from being taken forward. Finally, government should account for maintenance and renewals spending separately to enhancements so that it does not get deprioritised.

There is no time to lose

Delivering the Commission's package of recommendations will ensure the UK has low carbon and resilient infrastructure for the coming decades, which can support economic growth across regions and protect the natural environment.

But the UK must act fast. This Assessment sets out the steps government should take to capitalise on the areas where the UK has already made good progress, and to catch up in those areas where it risks falling behind.

While meeting the UK's economic infrastructure needs will incur significant, if manageable, costs, the costs of inaction would almost certainly be greater. The UK has been here before: the inadequacies of infrastructure today reflect past failures to act and invest for the long term. Policies have too often been delayed where the benefits of acting earlier would have outweighed the initial costs. Rather than repeating this mistake, government must act now to secure infrastructure that is fit for the future. Implementing the Commission's ambitious set of recommendations will require bold decisions, long term thinking, and support for households during the transition. The transformation of the UK's infrastructure will require determined political leadership at both national and local level. It will also demand close collaboration between government, regulators and industry.

The good news is that significant benefits can be realised for households, businesses and communities across the UK — and crucially, they can be achieved in a way that is affordable and fair.

Upgrading the UK's economic infrastructure offers households a wide range of benefits

Our recommendations will help improve quality of life and save money for people across the country

The examples below represent the expected outcome for a typical household if the Commission's recommendations are accepted fully and implemented on our proposed timescales

Improvements to the national road network could improve connectivity across and within regions by an average of **7.4%**

Lower income households will be helped particularly by falling bills (which make up a larger proportion of their total expenditure than in higher income households)

Electric vehicles will reduce fuel and running costs for motorists, cut carbon and improve air quality

By 2050, heat pumps will provide heating for most homes, reducing energy bills. To get there, lower income households should not have to pay the upfront costs, while others will have access to a **£7k** subsidy

By 2030, gigabit capable broadband should be available to every home, with 5G coverage expanding over the following years

Average household spending on infrastructure services will drop by at least **£1,000** between now and the mid 2030s

By 2035, **65%** of household municipal waste should be recycled – up from 45% today – with further progress over following years

By 2055, action to reduce surface water flooding should reduce the number of properties at highest risk by **60%**

Engaging with stakeholders

Since the start of the process for this Assessment, the Commission has sought input from a wide range of expert sources across the UK. From elected mayors leading regional growth strategies to investors; and from the largest utility network operators to community collectives generating their own energy, the Commission has spoken with hundreds of people in the course of forming this Assessment.

Following the publication of the Baseline Report in November 2021, over 100 organisations responded to a call for evidence, offering insights on the key challenges identified. Expert external panels on regional growth, net zero and climate resilience have complemented this, offering incisive insights and challenge to the Commission's work throughout the process.

The Commission's own Design Group and Young Professionals Panel both provided valuable perspectives on the emerging recommendations in this Assessment, drawing upon their own wider engagement work as well as their direct experience across relevant sectors.

Figure 3: The Commission has sought input from experts across the UK

Commission engagement in the run up to the second National Infrastructure Assessment



42 policy roundtable sessions held with public and private sector stakeholders since January 2022



Commissioners and Chief Executive held over 130 hours of one-to-one meetings with ministers, government officials, and political and industry leaders



Over 500 hours of one-to-one meetings with a wide range of stakeholders across all six sectors of the Commission's remit



Commissioners and senior staff spoke at 100 conferences and events

Source: Commission analysis. Numbers are approximate.

The Commission also embarked on a series of visits to towns and cities in England, covering both rural and urban areas, holding roundtables with Combined Authority mayors and their officials alongside representatives from infrastructure operators and other businesses. The visits enabled Commissioners to engage with community groups and to tour pioneering infrastructure developments like Redcar's Teesworks zone, the Future Fens initiative enhancing nature based resilience in East Anglia, and Langarth Garden Village, a low carbon new town near Truro.

Together, this huge amount of data, delivery expertise and policy input have contributed significantly to the final shape of this second Assessment.

Highlights of the Commission's programme 2022 to 2023



London



Birmingham



Bristol



Manchester

1. The challenges ahead



Economic infrastructure is pivotal to addressing some of the biggest challenges facing the UK: decarbonising the economy, boosting economic growth, and improving resilience and the environment. Proactively tackling these challenges provides an opportunity to bring major benefits to the UK. Government, regulators and industry must act urgently.

While economic infrastructure performs well in some areas, in others there are significant deficiencies that are holding the UK back. These include under investment in transport systems in regional English cities, not building any major water supply reservoirs in England in the last 30 years, leaving too many properties at risk of flooding, and stagnant recycling rates for a decade. This situation must improve.

How infrastructure performs today

The first National Infrastructure Assessment was published in July 2018. Since then, it has shaped infrastructure policy across sectors. The government's National Infrastructure Strategy,¹ a formal response to the first Assessment, aligned with the Commission's recommendations, and there has been significant progress on many of the recommendations, including:

- **Access to gigabit capable broadband:** The government has set out a clear vision to deliver gigabit capable broadband to at least 85 per cent of UK premises by 2025, and deliver nationwide coverage by 2030. Currently around 75 per cent of premises have gigabit capable broadband — up from five per cent in 2018.²
- **A shift to renewable electricity:** There has been a shift towards a highly renewable electricity system, with around 40 per cent of electricity generated by renewable sources in 2022 — up from less than ten per cent in 2010.³
- **Electric vehicles:** Following the Commission's recommendation that charging infrastructure should be delivered to support electric vehicles, sales of electric vehicles have increased sharply and government has put in place policy to phase out sales of new petrol and diesel cars.⁴
- **Flooding:** Between 2021 and 2027 the government has committed to investing £5.6 billion to reduce the risk of flooding.⁵
- **Drought resilience:** Government and the water industry in England have taken on the Commission's recommendations to increase water supply and reduce leakage, although a lot more still needs to be done.⁶
- **The UK Infrastructure Bank:** In June 2021, government launched the independent infrastructure financing institution the Commission recommended be established following the UK's loss of access to the European Investment Bank.⁷
- **Transport devolution:** Following the Commission's recommendation that there should be greater devolution of transport budgets, government established the five year City Region Sustainable Transport Settlements for Combined Authorities.⁸

However, in other infrastructure areas, the quality of infrastructure services provided to the public needs to urgently improve:

- little progress has been made to decarbonise heat, although the technologies to do so already exist
- emissions from transport have not been declining (Figure 1.2), despite improvements in engine efficiency, and, although electric vehicle charge point numbers are increasing,⁹ the pace needs to accelerate to enable the transition to electric vehicles
- asset maintenance issues undermine performance in some sectors, including ageing and leaky water pipes and potholes in local roads¹⁰
- about 900,000 properties in England have a more than one per cent chance each year of being flooded by rivers and the sea and around 910,000 properties have a more than one per cent chance of flooding from surface water¹¹
- the number of serious pollution incidents caused by water company assets remains unacceptably high; moreover in 2021 only 16 per cent of water bodies achieved good ecological status¹²
- no major water supply reservoirs have been built in the last 30 years to tackle the increasing risk of drought¹³
- recycling rates have plateaued and emissions from waste remain too high, while the total waste generated in England is increasing¹⁴
- in many major regional English cities it takes too long to reach city centres¹⁵
- there are too many journeys between towns and cities on major roads across England that are slow or indirect, creating barriers to trade.¹⁶

In addition to underperforming infrastructure services in some areas, over the last two years the cost of some infrastructure services has risen dramatically. For example, in 2022 the government intervened to stop the average gas and electricity bill from exceeding £2,500 a year.¹⁷ This still represented a significant increase on the average bill, which in 2019 had been around £1,250 a year.¹⁸ The Commission is acutely aware of the challenges households are currently experiencing in the face of rising costs of living.¹⁹ Infrastructure policy will only be effective if it is affordable for households across the country and with different levels of income. Taken together, if the Commission's recommendations were implemented, they would place bills overall on an enduring downward trajectory. More detail on this is set out in Chapter 5.

Recent costs increases for households underline the importance of keeping the cost of building economic infrastructure under control. The cost of building economic infrastructure in the UK is high by international standards.²⁰ Recent years have seen even more acute pressures from high levels of construction inflation.²¹ The UK must get better at controlling the costs of major infrastructure projects overall. Part of this comes from improvements in the way infrastructure projects are delivered including the approach to procurement, construction and project management, the use of digital tools, and the capability of government and other infrastructure operators to act as an intelligent client. The Infrastructure Projects Authority advises government on best practice in infrastructure delivery.²² But part of the solution also comes from having greater policy stability and long term plans, removing barriers, and improving infrastructure decision making — all areas covered by this report.

Taking advantage of strategic opportunities

The Commission has identified three cross cutting strategic opportunities that economic infrastructure is key to seizing:

- energy security and reaching net zero
- supporting growth across all regions
- improving resilience and the environment.

These are linked to the Commission's own objectives to: support sustainable economic growth across all regions of the UK, improve competitiveness, improve quality of life, and support climate resilience and the transition to net zero carbon emissions by 2050.²³

The Commission's remit extends to economic infrastructure within the UK government's competence. The Commission's role is to advise the UK government, but the Commission works with both the UK government and the devolved administrations where responsibilities interact.

Figure 1.1: There is substantial devolution across the Commission's remit

Devolved administration responsibilities, by infrastructure sector

	Northern Ireland	Scotland	Wales
Digital	Reserved	Reserved	Reserved
Energy	Devolved, except nuclear	Reserved, except energy efficiency	Reserved, except energy efficiency
Flood risk	Devolved	Devolved	Devolved
Transport	Devolved	Largely devolved	Devolved, except rail
Waste	Devolved	Devolved	Devolved
Water and sewerage	Devolved	Devolved	Devolved

Source: Commission analysis of devolution legislation and agreements

All recommendations made in this Assessment apply only to areas within UK government competence, and investment figures are calculated on this basis. All costs presented in this document are in 2022 prices unless otherwise stated.

Energy and reaching net zero

To create a net zero economy by 2050 the UK needs to move away from gas and oil. To meet its legally binding climate targets, the UK must reduce its overall greenhouse gas emissions by 78 per cent compared to 1990 levels by 2035, and to net zero by 2050.²⁴ Good progress has been made: greenhouse gas emissions in 2022 were around 45 per cent lower than in 1990.²⁵ However, the vast majority of recent progress has been driven by decarbonising electricity generation,²⁶ while in other sectors, progress has been much slower (see Figure 1.2).²⁷ Urgent action is needed to put the UK on track to meet the Sixth Carbon Budget and achieve a net zero economy by 2050.²⁸

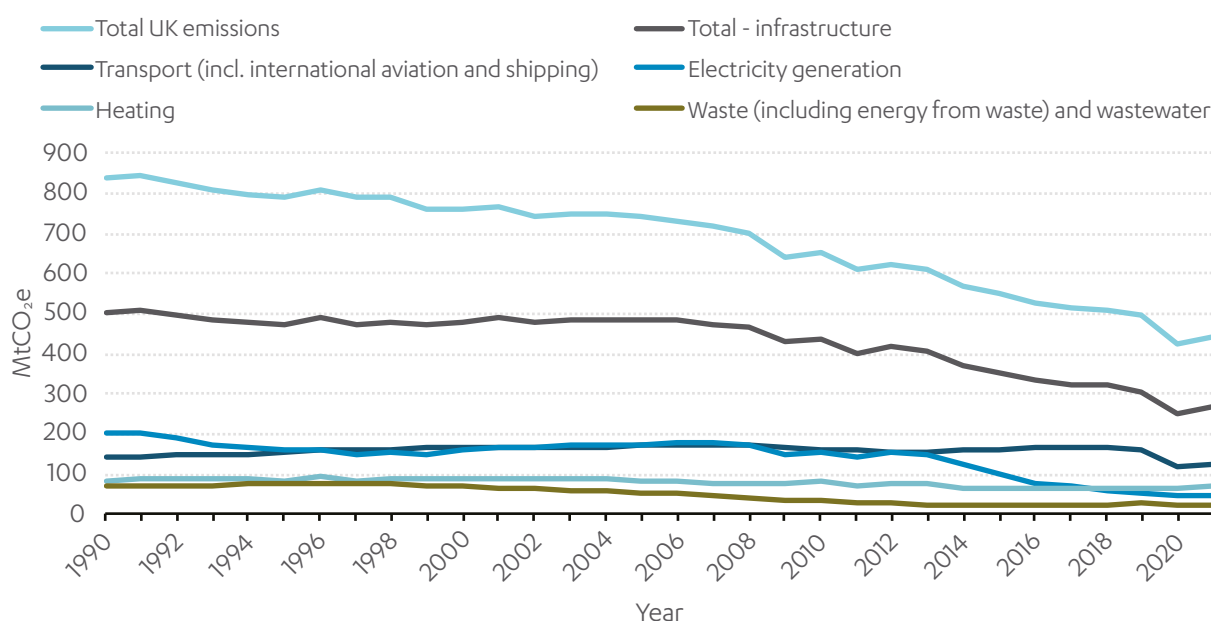
Over two thirds of the UK's greenhouse gas emissions come from economic infrastructure:

- 55 MtCO₂e (15 per cent) from generating electricity, which needs to fall to less than 10 MtCO₂e by 2035
- 90 MtCO₂e (20 per cent) from heating buildings, which needs to fall to around 45 MtCO₂e by 2035
- 100 MtCO₂e (25 per cent) from fueling vehicles, which needs to fall to around 50 MtCO₂e by 2035
- 75 MtCO₂e (20 per cent) from powering industry, which needs to fall to around 20 MtCO₂e by 2035.²⁹

For almost all sectors, moving away from fossil fuels means switching to electricity. Running the economy on cheaper, reliable low carbon electricity is the best way to cut emissions.

Figure 1.2: Emissions from infrastructure have fallen, but there is more to do

Annual greenhouse gas emissions by infrastructure sector, 1990 to 2021



Source: Commission calculations using Department for Business, Energy & Industrial Strategy (2023), Final UK greenhouse gas emissions national statistics: 1990 to 2021

Note: Industrial emissions are not included in economic infrastructure in this chart.

Decarbonising the economy will also bring significant economic benefits. Moving away from internationally traded fossil fuels will reduce the country's exposure to volatile fossil fuel markets, helping to protect living standards. Moving at pace in the global transition to low carbon technologies gives the UK the best chance of building international competitive advantages in some sectors. Perhaps most importantly, creating cheaper energy in the long term — a key input into almost all economic activity — will lower costs for firms and households across the economy, generating productivity and economic growth benefits to the UK.

Supporting growth across all regions

The UK suffers from persistent slow growth and entrenched regional inequalities. Since the mid 2000s, UK productivity has fallen further behind comparator countries such as France, Germany, and the United States.³⁰ In addition, the UK has long standing and self reinforcing variations in economic outcomes between and within regions.³¹ One of the reasons for this poor economic performance in recent years is low levels of investment in the UK economy compared to international peers: in the 40 years to 2019, investment in the UK averaged around 19 per cent of GDP, the lowest in the G7.³²

Cities can play a central role in boosting both regional and national growth. They have the highest employment density and highly productive businesses, and economic growth in cities has big spill over benefits on the wider regions in which they are located.³³ Most economically successful towns in England are close to successful cities.³⁴ But some of the largest English cities are underperforming their potential.³⁵ London is the only major city that outperforms national productivity.³⁶ This is not the case in comparable countries, where many cities outside the capital have above average productivity (see Figure 1.3). Analysis suggests that the 'productivity gap' in major English cities is in the tens of billions of pounds per year.³⁷ The productivity of underperforming areas needs to be improved, while at the same time maintaining the productivity growth of high performing areas.

While infrastructure cannot solve these problems alone, better infrastructure is necessary for improving productivity growth in certain places.³⁸ Effective transport infrastructure can facilitate trips within cities and more efficient trade of goods and services between them.³⁹ However, transport infrastructure in England does not perform well enough:

- England's largest regional cities are congested, and their public transport networks underperform relative to comparable European cities⁴⁰
- there are wide variations in interurban connectivity between similar places,⁴¹ with rail journeys between major cities in the Midlands and the North often slow, and the services unreliable.⁴²

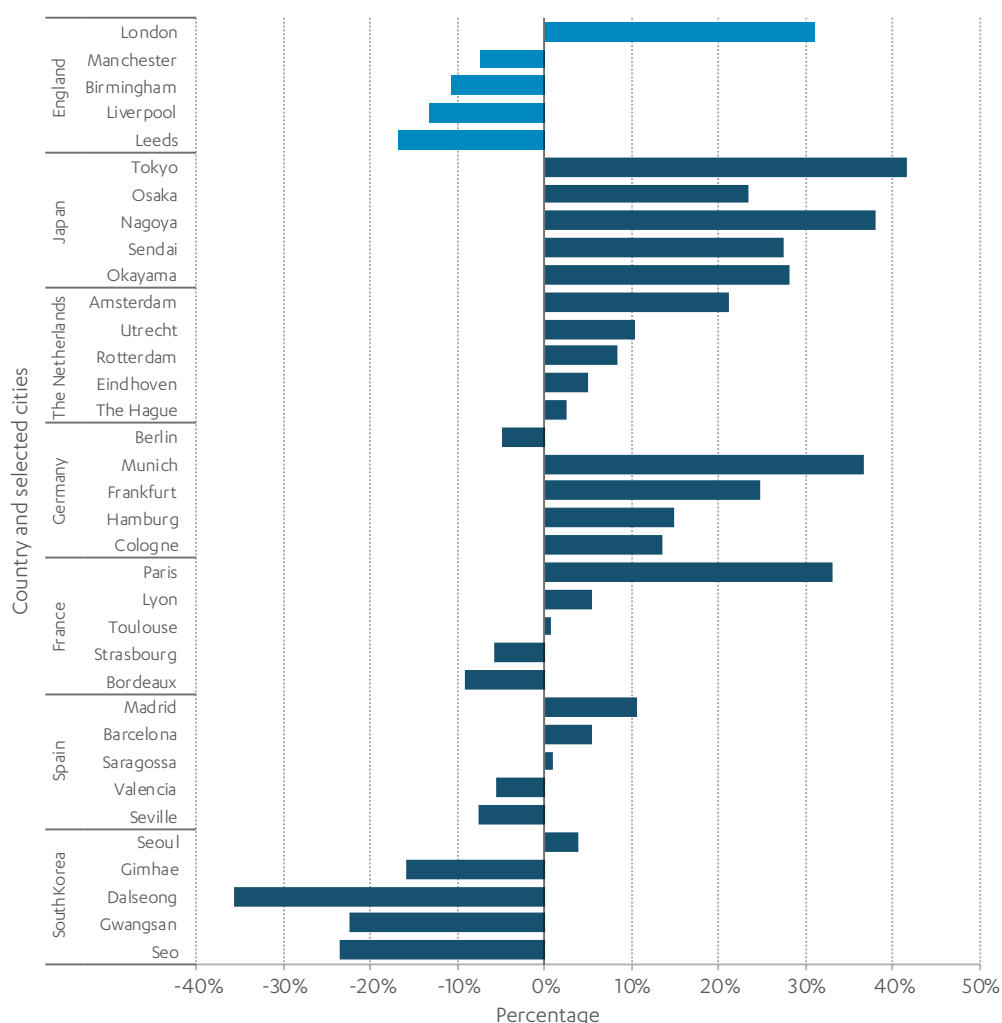
The quality and reliability of public transport in major cities needs to be brought much closer to that of London. At the same time, London's transport system must be maintained at its world class level, given the important role London plays both regionally and nationally. Improving strategic road and rail links should also be focused on places where it can have the most impact, rather than spreading investment too thinly. Improving transport infrastructure impacts more than just economic growth; it will also have a positive impact on living standards more generally.⁴³

Broadband and mobile networks also play a role in boosting economic growth and improving living standards. Past investments in digital infrastructure have supported significant economic growth. For example, it has been estimated that between 2002 and 2016 there was a cumulative 6.7 per cent increase in UK GDP due to increased broadband adoption and speed improvements.⁴⁴ Delivering nationwide coverage of gigabit broadband and new 5G services can stimulate innovation and help to improve productivity in some sectors.

Failure to provide adequate economic infrastructure can also act as a constraint on growth. There are examples of lack of capacity on the electricity networks leading to delays of over 15 years in grid connections being reported.⁴⁵ This is preventing both electricity generation projects from moving ahead and business that need to connect to the electricity network from delivering projects. Similarly, in some areas of the country water scarcity is preventing potential new housebuilding.⁴⁶ These challenges are discussed in Chapters 2 and 4 respectively.

Figure 1.3: English cities have productivity below the national average, unlike international comparators

GDP per worker, percentage difference compared to national average, in England and comparable countries



Source: OECD (2021), Labour productivity, Metropolitan areas; OECD (2021), Level of GDP per capita and productivity for 2018 (2016 for France and Japan)

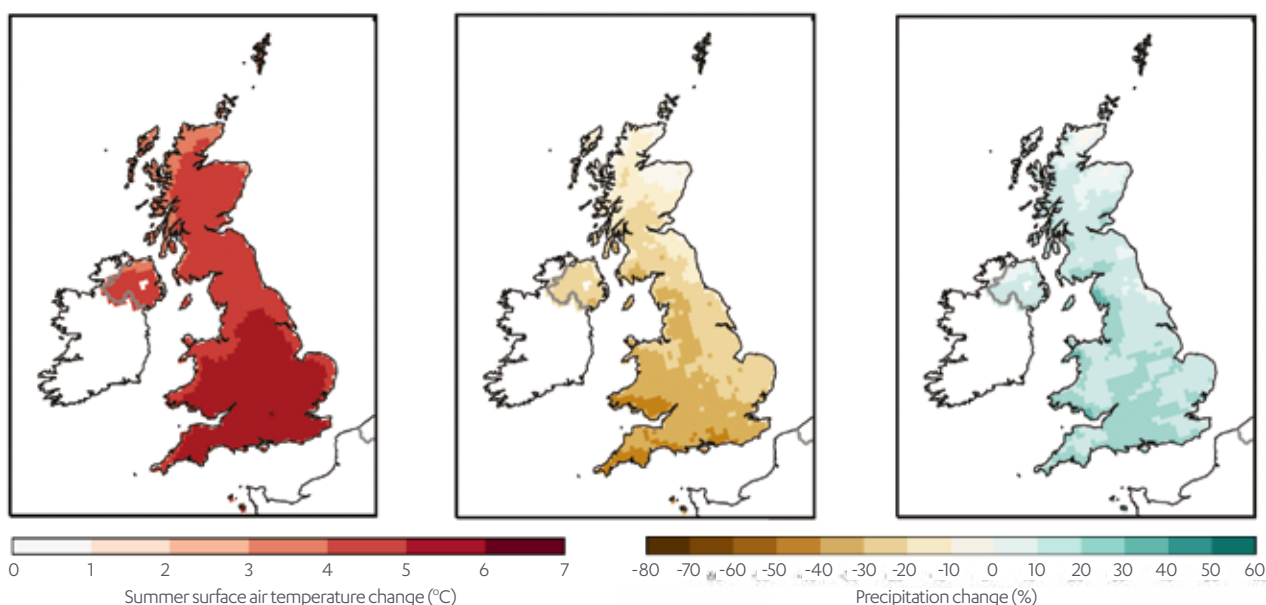
Improving resilience and the environment

A resilient infrastructure system is critical to protecting the economy and preventing disruption and damage to people's lives. The UK's economic infrastructure has proved fairly resilient to shocks and stresses over recent decades, but challenges are increasing. Since 2000, the number of service interruptions in the energy and water sectors has, on average, been falling.⁴⁷ In contrast, service interruptions in transport have been trending upwards.⁴⁸ Recent shocks, such as the energy price crisis, have revealed vulnerabilities and highlighted the interdependence between infrastructure sectors.⁴⁹ In the coming decades, risks from climate change will increase due to wetter winters, rising sea levels, and drier summers (see Figure 1.4).

To respond to this, the UK's infrastructure must become more resilient. The Commission's social research demonstrates that the public has low levels of confidence in the resilience of the UK's infrastructure.⁵⁰

Figure 1.4: Climate change is likely to lead to hotter, drier summers and warmer, wetter winters in the UK

Met Office central projections of forecast changes for mean summer surface air temperature (left), summer precipitation (centre) and winter precipitation (right) for 2061-2080, relative to a 1981-2000 baseline



Source: Met Office (2018), UKCP18 Land projections: Science Report

The natural environment is in decline. Globally, the stock of natural capital is decreasing, species extinction is accelerating and ecosystem health is deteriorating.⁵¹ The latest biodiversity indicators in the UK show declines in the status of threatened habitats and species, as well as increased pressure from invasive species.⁵² While economic infrastructure is not the principal cause of this decline, it has contributed to it.⁵³

In recent years, the UK has taken action to try to address this. The government set out targets for improving the natural environment in the 25 Year Environment Plan.⁵⁴ These include targets and ambitions on clean air, clean and plentiful water, thriving plants and wildlife,

minimising waste and using resources from nature more sustainably and efficiently.⁵⁵ Meeting these targets will help support a more productive economy and boost living standards.⁵⁶ Well designed and effectively delivered economic infrastructure, such as water resource or waste systems, have a key role to play in meeting the government's goal of improving the environment over coming decades.

Box 1.1: Social research for the second Assessment and the Baseline Report

In June 2021, the Commission carried out social research to help inform the Baseline Report that preceded this Assessment, and to support the identification of strategic opportunities.

The research found that around two fifths of people saw leading the fight against climate change as a top priority for UK infrastructure over the next 30 years.⁵⁷ This showed an increase on the first Assessment, when around a quarter of people prioritised climate change. Long term planning and investing now to save costs in the long term were also priorities for the public.⁵⁸

On infrastructure investment, two fifths of respondents felt that their region received lower than average levels of infrastructure investment. This was particularly the view from respondents in North East England, North West England, Yorkshire and the Humber and Wales. A quarter of respondents felt that supporting regional growth to rebalance the economy should be a key factor in shaping the vision for the UK's infrastructure.⁵⁹

The research also found that the impact of infrastructure on the environment was the most important consideration that the public wanted prioritised in infrastructure planning. The need to focus on the environment was seen as an overarching 'end goal' driving timely investment in quality infrastructure which is resilient and leaves a positive legacy for future generations.

In 2023, the Commission carried out further social research to inform its recommendations. The research again found that long term planning and climate change were seen as the most compelling visions for infrastructure strategy in the UK. The research also found that the cost of living crisis was the most important contextual factor affecting how people viewed infrastructure.⁶⁰

The Commission undertook a specific piece of social research to better understand how people with different protected characteristics experience and view infrastructure, including any barriers that they may face.⁶¹ This research found that protected characteristics play a role in shaping people's specific, day to day experiences of infrastructure.⁶² However, it also found that income and socioeconomic background were front of mind when thinking about infrastructure, as those from poorer socioeconomic backgrounds or those on lower incomes were more likely to struggle with the everyday costs associated with access.

Making good infrastructure policy

This National Infrastructure Assessment sets out recommendations to meet these challenges and make the most of the opportunities they present. The Commission has used five policy principles to guide its recommendations:

- **Removing barriers and accelerating decisions:** Currently there are too many barriers that slow down infrastructure decision making and delivery. These undermine the effectiveness of public spending and make the UK a less attractive place to invest. Policy must change to facilitate faster progress.
- **Taking long term decisions and demonstrating staying power:** Repeatedly changing policy creates uncertainty for infrastructure operators and investors, which deters investment. It also slows the development of supply chains, driving up costs.
- **Pace, not perfection:** Government has spent too much time on small scale changes and repeated consultations. Ambitious goals must be backed up by bold policies and effective implementation. To make the rapid progress required, options must be closed down where the risk of delay is greater than the risk of making a suboptimal decision.
- **Furthering devolution:** Decisions made at the local level are better able to reflect local preferences, circumstances, and information, and plans can be implemented more effectively at a local level too. When devolution is done well, in a way that doesn't lead to fragmentation, it is associated with productivity benefits and reduced regional differences.⁶³ Historically, the UK has struck the wrong balance between risk sharing nationally and local autonomy over spending or taxation.
- **Adaptive planning:** There is inevitable uncertainty associated with long term infrastructure policy making. Decision makers must not be continually buffeted by this uncertainty, nor ignore it. In this Assessment, the Commission sets out a portfolio of policies that use adaptive pathways to effectively navigate uncertainty.

The six economic infrastructure sectors within the Commission's remit all interconnect and so the Commission has taken a systems thinking approach.⁶⁴ The Commission has used systems thinking to understand the complex interaction between different sectors — from mapping the interaction between transport decarbonisation and the transformation of the energy grid to considering the risks of cascading resilience failures across energy, telecoms, and transport.

It will not be possible or desirable for the UK to 'build its way out of every problem'. Action on the demand side is also needed. This Assessment makes a series of recommendations to support behaviour change in a way that is fair and affordable, including: demand side response in energy (tools and incentives to reduce or reschedule energy usage at times of peak demand) to reduce costs of the electricity system, traffic management measures to support public transport and reductions in the amount of water each person uses. The public should be supported through a mix of financial incentives such as support with the costs of low carbon heating, smart technology such as increased use of smart water meters, and public information such as education campaigns to help consumers understand their water consumption.

However, better policy alone is not enough to create affordable, low carbon, and resilient infrastructure services. The Commission's recommendations need to be implemented effectively to rapidly deliver projects on the ground.

The Commission has produced and commissioned extensive and wide ranging analysis to support the development of the recommendations in this Assessment. The Commission's Young Professionals Panel has also produced a separate report setting out their own priorities for future infrastructure. Their proposals focus on reaching net zero and enabling a just transition to a lower carbon, more climate resilient economy. All supplementary documents are available on the Commission's website.

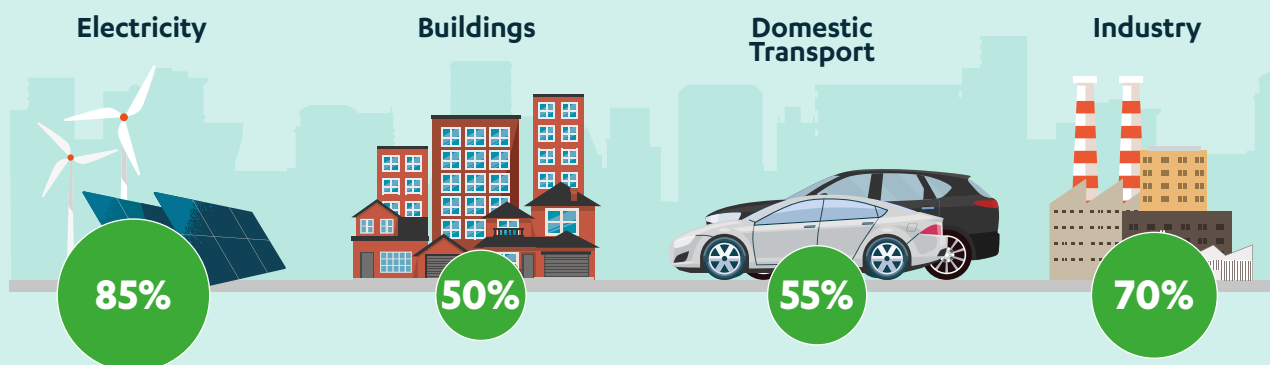
2. Energy and reaching net zero



The country can move away from fossil fuels and have decarbonised, secure energy and lower bills

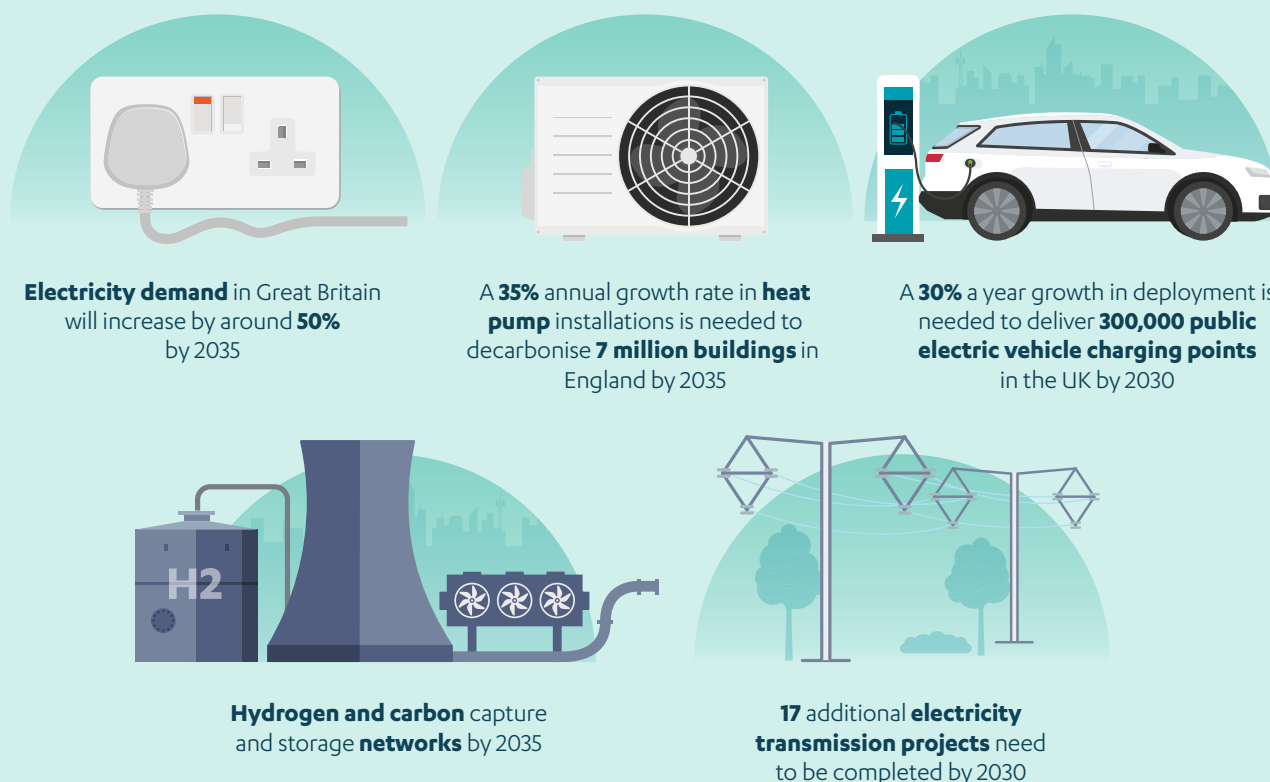
Currently, around 80 per cent of the UK's energy demand is met by fossil fuels

Every sector of the economy will need to make substantial reductions in fossil fuel use to lower emissions:



Percentage reductions in emissions by 2035 to meet the Sixth Carbon Budget

Significant changes to the energy system will be needed



Sources: DESNZ, Aurora, Commission modelling, DfT

The UK can move away from fossil fuels and have decarbonised and secure energy. For most sectors, this means switching to electricity. Electricity is much more efficient than fossil fuels, as well as being cleaner and reliable. New networks for low carbon hydrogen and carbon capture and storage will also support a decarbonised economy. Not only will car owners switch to electric vehicles, but households will swap their gas boilers for cleaner, more efficient heat pumps or heat networks. While these technologies should roughly halve energy costs for households in the coming decades, the transition must be carefully managed to ensure the public are supported with the upfront costs and the living standards of those least able to pay are protected.

Phasing out the use of fossil fuels to generate electricity, heat homes, and power vehicles and industry will support energy security and is essential for the UK to meet its legally binding climate targets. Action is now urgent with only 12 years left to meet the Sixth Carbon Budget.

Government will need to accelerate the deployment of renewable generation and flexible technologies that can provide electricity if the sun isn't shining or the wind isn't blowing. Policies should support the deployment of electricity storage, demand side response and incentivise investment in large scale hydrogen and gas with carbon capture and storage power stations. More demand for electricity also means more investment will be needed in transmission and distribution cables and this must keep pace with demand. Government should also establish a reserve of energy that can mitigate the effect of future price shocks.

There must be a comprehensive, long term and funded plan for phasing out gas boilers and replacing them with heat pumps or heat networks. The main focus of policy should be supporting — not forcing — households to make the switch. Kick starting the market for electric heating will require government to commit long term funding for decarbonising the public sector estate, social housing and the homes of those on lower incomes. It will also be necessary for government to support other households and small businesses to make the switch to heat pumps by providing an initial upfront subsidy of £7,000, access to zero per cent financing and by ensuring it is cheaper to run a heat pump than a gas boiler. Government should rule out supporting hydrogen heating to enable an exclusive focus on switching to electric heating. Government also needs a plan for phasing out the use of fossil fuels which addresses how the gas network will be decommissioned.

As deploying electric cars and vans is the single biggest action needed to decarbonise surface transport, government should ensure there is a nationwide network of public charge points, reaching at least 300,000 chargers by 2030. To build consumer confidence, these charge points must be spread across all parts of the country. Recognising uncertainty in whether targets will be met, government should monitor progress against its transport decarbonisation plans and be prepared to adapt its approach if necessary.

Government should develop a comprehensive strategy to meet its industrial decarbonisation target and support the UK's industrial activity as buyers increasingly demand low carbon products. Government should coordinate and support the delivery of hydrogen and carbon capture and storage infrastructure across the country to facilitate decarbonisation where electrification is not a viable option.

The challenge ahead

Around 80 per cent of the UK's energy demand is met by fossil fuels.⁶⁵ The majority of this demand comes from electricity generation, heat, surface transport and industry.⁶⁶ In the coming decades, the UK will move away from fossil fuels by decarbonising the way electricity is generated, homes are heated, vehicles are fuelled and industry is powered.

Moving away from fossil fuels means predominantly switching to electricity, which, in turn, will deliver lower energy bills in the long term. Electricity is not only cleaner than fossil fuels, but also more efficient. This will require a fundamental change in energy infrastructure. Over the next 30 years this will include:

- a build out of a secure, flexible, larger and low carbon electricity system, continuing the good progress made so far on decarbonising electricity generation
- a switch to electrified heat by incentivising the rollout at pace of heat pumps and heat networks to replace gas boilers in homes and businesses
- a continued rollout of electric vehicles and the charging infrastructure to support their use, replacing petrol stations
- support for industry to run on electricity where possible, but, where it is not, establishment of new infrastructure for low carbon hydrogen and carbon capture and storage.

Moving away from fossil fuels will bring multiple benefits to the UK:

- **Energy security:** The UK is a net importer of fossil fuels.⁶⁷ Reliance on fossil fuels means exposure to geopolitical shocks that impact the price of these internationally traded commodities.⁶⁸ Domestically generated renewable electricity does not require fuel inputs, so they will improve energy security. And the new risks renewable generation poses, brought on by its reliance on the weather, can be mitigated.
- **Price stability:** An energy system dominated by electricity produced from renewable generation is capital intensive with long lasting assets and few fuel inputs. This makes it inherently less price volatile, and therefore less susceptible to future price shocks.⁶⁹
- **Affordability:** Investing now will drive lower energy prices over the long term, benefitting households and businesses. The average household cost of energy should roughly halve compared to today's high levels, as set out in Chapter 5.
- **Productivity:** Lowering the cost of energy should in turn improve productivity, supporting growth across the economy.
- **International competitiveness:** There is an opportunity for UK businesses to capture market share in global low carbon supply chains, where they can build competitive strengths. Decarbonising the energy supply, lowering bills and improving the stability of prices also offer the chance for UK services and manufacturing to stay internationally competitive.
- **Quality of life:** Electric heating and transport will improve air quality in homes and streets.⁷⁰ Making homes more energy efficient will leave the housing stock in a better state for future generations.

Fundamental change in energy infrastructure is needed. Much of the transition will happen over the next 12 years to meet the Sixth Carbon Budget. That is a big task, but it is achievable. Most of the technologies already exist. Many, like renewable electricity generation, are already cheaper than fossil fuel alternatives. Others, like electric vehicles, will be cost competitive within the next decade.⁷¹ And the UK has successfully delivered rapid transformation in energy infrastructure before:

- in the 1950s, an electricity ‘supergrid’, comprising 4,000 miles of transmission lines, was built in 12 years⁷²
- in the 1960s and 70s, all gas appliances were converted from town gas to natural gas in ten years⁷³
- in the 1990s ‘dash for gas’, the UK built around 40 gas power stations, equivalent to 20GW of capacity in ten years, with a maximum annual rollout of three GW.⁷⁴

Significant spending in the energy system, from both the private and public sector, will be necessary. Policy decisions by government will need to support increased investment by the private sector. Most energy infrastructure is built and operated by the private sector and paid for through energy bills.

But government spending will also be needed to deliver the scale of change at the necessary pace. The Commission recommends that government spending in the energy system is focused on heat decarbonisation. This transition will not happen without it. Enhanced support for households on lower incomes will also enable the transition to be affordable and fair.

To maximise the benefits this transition will deliver, government needs to act, and fast. Pace is needed to ensure opportunities are not lost.

Building a secure, flexible and low carbon electricity system

Currently, 18 per cent of fossil fuel demand is used in electricity generation.⁷⁵ This must reduce rapidly to support decarbonisation across the economy and deliver a more resilient, less price volatile and cheaper electricity system.

Electricity demand is set to increase by around 50 per cent by 2035 as surface transport and heating are electrified and industry is increasingly powered by electricity, or hydrogen which will be produced using electricity.⁷⁶

Decarbonising electricity requires rapid and decisive changes, including:

- growth in renewable electricity generation to meet increasing demand
- increased volumes of flexible supply, which will also need to be low carbon, and demand side response (tools and incentives to reduce or reschedule energy usage at times of peak demand)
- an end to the use of unabated gas fired generation which is high carbon
- transformation in electricity networks to provide the capacity needed to manage more demand and more dispersed supply
- increased resilience to shocks.

Low carbon electricity generation

By 2035, domestically generated renewable electricity can meet the vast majority of electricity demand.⁷⁷ Significant reductions in emissions from the electricity system have already been realised, driven by government policies to remove coal generation and support renewables. But the electricity system is still far too carbon intensive and reliant on gas generation.

Renewable generation from wind or solar is well established and delivers the cheapest electricity. By 2035, modelling for the Commission suggests that around 60GW of offshore wind and 70GW of solar generation will be needed.⁷⁸ These volumes are in line with government's goals.⁷⁹ Onshore wind, because it offers one of the cheapest forms of electricity,⁸⁰ should also be scaled up. By 2035, 25GW should be deployed, which will require further reduction in current deployment barriers.⁸¹

Nuclear generation will continue to contribute to a low carbon electricity system. By 2035, eight GW of capacity may be available if Hinkley Point C and Sizewell C come online and accounting for older plants retiring as planned.⁸² A one by one approach to deploying large scale plants, as the Commission recommended in the first Assessment, enables a skills base to be maintained without over committing to a technology that has proven to be hard to deliver on time and is more expensive than alternatives.⁸³ Government is developing the option to deploy small or advanced modular reactors as they may also play a role in the longer term.

Government's Contracts for Difference scheme is instrumental in supporting renewable generation deployment.⁸⁴ It has driven cost reductions and can help novel technologies like tidal stream and floating offshore wind to mature. The scheme demonstrates the benefits of stable, long term policy making. However, the scheme will also have to adapt to reflect the wider economic situation. This year's auction resulted in no bids from offshore wind developers.⁸⁵ Next year's auction parameters should reflect shifts in financing and manufacturing costs and restore investor confidence.

A flexible electricity system

Electricity supply needs to match demand at all times of the day and year. Supply from a blend of renewable and nuclear generation will not always be sufficient to meet demand. These shortfalls in supply can be addressed by increasing generation from flexible sources or reducing demand through demand side response. Flexibility also helps ensure that generation is used most efficiently. Without additional flexibility more generation will be needed to meet the peaks in demand.

The need for flexibility is not new, but the variability of renewable generation will mean that more flexibility is required. The volume of electricity that solar panels and wind turbines generate is dependent on the amount of sunlight and wind and therefore cannot be guaranteed at all times.

To deliver a decarbonised electricity system the flexibility currently provided by unabated gas fired generation, which can be switched on and off to meet demand, needs to be replaced by low carbon alternatives.

Box 2.1: Defining flexible technologies

The UK Energy Research Centre has identified three characteristics that are important for flexible technologies:

- **Flexibility:** the technology can adjust quickly to balance supply and demand
- **Schedulability:** performance can be planned with confidence at a few days' notice
- **Persistence:** the technology can continue to deliver for several days and weeks.⁸⁶

Persistence is crucial to ensure that the electricity system can manage imbalances in demand and renewable supply over days, weeks and seasons.

The electricity system needs flexible technologies that can provide both enough capacity and enough volume of energy. **Capacity** is measured in gigawatts (GW). This is a measure of how much energy a technology can transfer at any one point in time.

Volume of energy is measured in terawatt hours (TWh). This is a measure of how much energy a technology can transfer over a specified period of time. One TWh is equal to a technology with one GW capacity running for 1,000 hours. For storage technologies, TWh is a measure of how much energy the technology can output before it is empty and needs to be recharged.

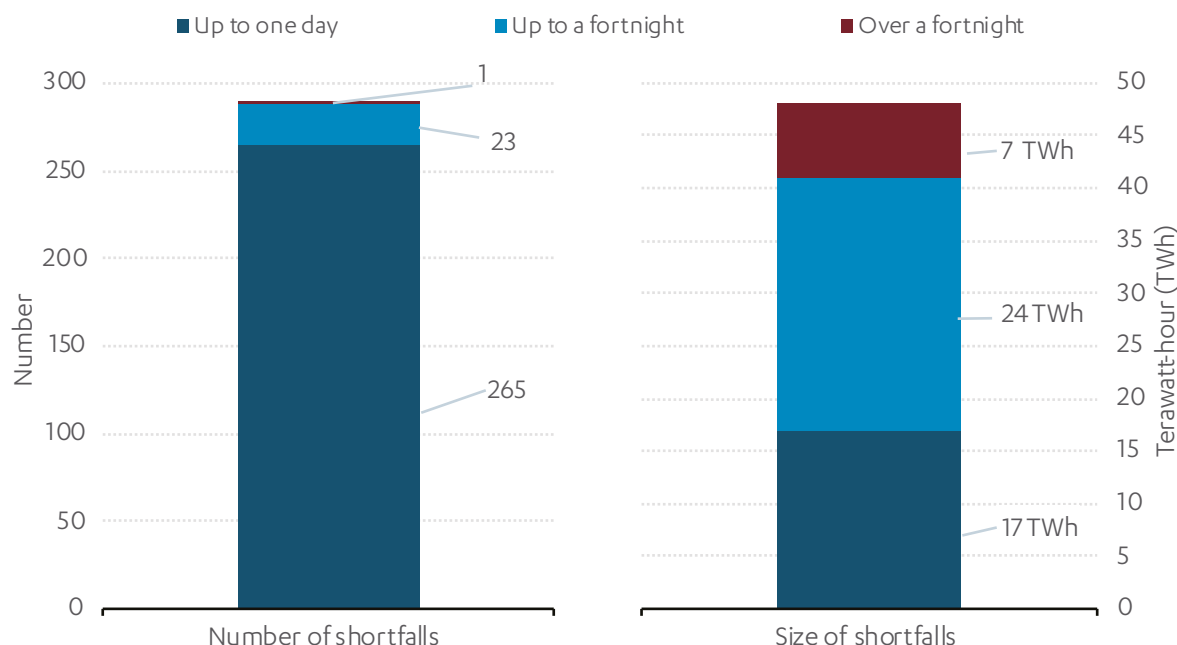
A range of technologies will replace the role of unabated gas fired generation in providing flexibility to the electricity system. The optimum technologies to use will vary depending on the time period:

- **Short term flexibility** (for flexibility within a day) can be provided through technologies such as interconnectors, energy storage (such as batteries, pumped hydro storage, compressed air or liquid air energy storage) and demand side response from households and businesses
- **Longer term (persistent) flexibility** (for days, weeks or seasons) will predominantly come from a mix of electricity generated by hydrogen and gas with carbon capture and storage.

Short term flexibility is needed more often, but long term (persistent) flexibility requires larger volumes of electricity across the year (see Figure 2.1).

Figure 2.1: Longer shortfalls occur less frequently but require much more energy

Number and size of shortfalls in an illustrative 2035 scenario



Source: Commission analysis of Aurora Energy Research (2023), The role of system flexibility in achieving net zero (A)

By 2035, modelling for the Commission suggests that 60GW of short term flexible capacity will be needed to provide a low cost electricity system.⁸⁷ There is currently around 15GW of low carbon supply side flexibility on the system.⁸⁸ The technologies that provide short term flexibility have different characteristics, so a portfolio of technologies will offer benefits to the system while minimising deployment risks. To support an efficient highly renewable system, two thirds of this target may be needed by 2030.⁸⁹

Government can support this level of capacity by ensuring that all technologies have routes to market by:

- Using the planned Review of Electricity Market Arrangements to develop policies that support deployment and making this a priority.⁹⁰
- Encouraging the Independent System Operator to apply market arrangements that allow the full range of technologies to participate in markets for balancing and ancillary services.⁹¹
- Bringing forward the promised policy framework to enable investment in electricity storage technologies.⁹²
- Incentivising households to participate in demand side response.⁹³ Demand side response means consumers changing when they use energy. Sending price signals to consumers and automation will be important to increasing the scale of response. Tariffs that incentivise shifting electricity use to times of lower demand and the rollout of smart enabled electric vehicle chargers and heating technologies will support this.⁹⁴
- Continuing to promote innovation funding to develop newer technologies that could provide flexibility at lower cost.

By 2035, modelling for the Commission suggests that 30TWh of longer term persistent flexible generation will be needed to manage the potential for prolonged shortfalls during winter.⁹⁵ This will predominantly come from a mix of hydrogen fired generation and gas generation with carbon capture and storage. To achieve this, it will be necessary for government policy to ensure that:

- there are enough power stations deployed to generate electricity when it is needed
- power stations have access to sufficient fuel to generate the volume of electricity needed.

Government should support multiple large scale hydrogen and gas with carbon capture and storage power stations to deploy by 2030, with a view to rapidly increasing deployment from then onwards. This will require an increase in current ambition on timescales and volumes.⁹⁶ A business model to support gas generation with carbon capture and storage has already been developed and the same will need to happen for hydrogen fired generation.⁹⁷ Both technologies offer similar levels of potential. Pursuing both manages the risk of slippage to the deployment timescales. These are first of a kind technologies which are not yet economic for the market to deploy, but evidence suggests they are deliverable by this date.⁹⁸ A similar speed of deployment for a similar technology has happened before — in the 1990s gas fired generation reached a maximum annual rollout of three GW.⁹⁹

Hydrogen storage will be essential to ensure access to sufficient fuel. Hydrogen can be produced when there is excess electricity and prices are low, stored for long periods of time and converted back to electricity when there are shortfalls in electricity supply. Hydrogen storage can also therefore support generation capacity to be used more efficiently.

At least eight TWh of hydrogen storage capacity will be needed by 2035.¹⁰⁰ This will provide enough storage to manage winters that are colder and less windy than average, providing additional resilience when there is lower renewable generation output or higher energy demand. Considering the possibility of several winters that are colder and less windy than average over multiple years could significantly increase the storage capacity that might be needed.¹⁰¹

The UK has thousands of TWh of theoretical storage capacity in the form of salt caverns and depleted oil and gas reserves.¹⁰² However, there is less than one TWh of hydrogen storage in the UK today.¹⁰³ The lead times for developing hydrogen storage can be up to ten years so action is needed now to meet the level the system needs.¹⁰⁴ The Commission is also making recommendations to ensure power stations have access to the hydrogen and carbon capture and storage infrastructure needed, which are covered later in the chapter.

Recommendation 1: Government should target a total of 60GW of short duration flexibility by 2035. Government should introduce policy in 2024 to enable this, ensuring all viable technologies have a route to market.

Recommendation 2: Government should by 2024 have in place a business model to support hydrogen fired generation and ensure that by 2030 multiple large scale power stations are deployed for both gas generation with carbon capture and storage and hydrogen fired generation. By 2035, deployment of low carbon gas generation should

be sufficiently scaled to provide 30TWh of persistent flexible generation to manage the potential for prolonged shortfalls during winter.

Recommendation 3: Government should target establishing a minimum of eight TWh of large scale hydrogen storage to be in operation by 2035.

An end to unabated gas fired generation

To fully decarbonise electricity generation, unabated gas fired generation must end. By 2035, actions to meet renewable generation targets and scale up flexible low carbon technologies should allow the contribution of unabated gas fired generation to fall to no more than two per cent of generation.¹⁰⁵ The UK has successfully taken action to reduce coal generation from 39 per cent of electricity generated in 2012 to two per cent by 2021.¹⁰⁶ Similar policies can drive the same reduction in unabated gas fired generation.

Government has proposed strengthening the requirements for new gas power stations to have clear decarbonisation pathways through conversion to hydrogen, or the use of carbon capture and storage.¹⁰⁷ These measures are welcome, but policy should be stronger. Future capacity market contracts should not provide unabated gas fired generation with contracts that extend beyond 2040. Unabated gas fired generation should be less economic to deploy than low carbon gas generation to accelerate the deployment of these technologies.

Preventing unabated gas fired generation operating in the wholesale, capacity and balancing markets from 2040 would provide a clear signal of government's intent. This would give greater clarity to the private sector on the trajectory for bringing gas off the system, allowing it to invest accordingly.

From 2040, security of supply can be safeguarded by allowing the Independent System Operator to turn on backup unabated gas fired generation, similar to the measures used to allow for coal generation over the winter starting in 2022. Deployment would only occur once all other mechanisms have been exhausted.

Recommendation 4: Government should phase out unabated gas fired generation so that it generates less than two per cent of electricity by 2035, and prevent unabated gas power stations from operating in the wholesale, balancing and capacity markets by 2040 at the latest. Actions to deliver this should include:

- **ensuring that carbon capture and storage enabled and hydrogen fired electricity generation stations deploy ahead of unabated gas power stations, through a combination of carbon pricing and emissions limits on new and existing unabated gas power stations**
- **shortening the length of future capacity market contracts for unabated gas power stations from the 2025 auction round, ensuring that these contracts do not extend beyond 2040**
- **allowing the Independent System Operator to turn on unabated gas power stations 'in extremis' to ensure security of supply.**

Transforming electricity networks

Investment in electricity transmission and distribution networks has not kept up with the changing nature and scale of demand and supply. Increasing network capacity at pace requires changes to planning, regulation and governance. The challenges and the solutions are well documented. Now the changes should be made.

The current planning system is a blocker to timely delivery of the electricity network. Delays in getting the necessary infrastructure built have in part been due to a lack of up to date National Policy Statements that reflect current government policy.¹⁰⁸ Implementing the Commission's recommendations on planning reform is essential for delivering the upgrades needed.¹⁰⁹

The regulatory system can also be improved. In taking decisions on network investment priorities, Ofgem balances the risks of over and underinvestment. It has taken positive steps recently to tilt the balance to unlock anticipatory investment in transmission infrastructure but can do more.¹¹⁰ The trajectory of demand is clear and there is a good understanding of where supply will predominantly come from. The risk of stranding network assets exists but is low. Investment ahead of need in networks will prevent cheap renewable generation going to waste when electricity cannot get from where it is made to where it is needed. Greater guidance from government, by giving Ofgem a net zero duty and publishing an up to date Strategy and Policy Statement, can support Ofgem's decision making.¹¹¹ Risks that do exist can be further mitigated through coordinated planning.

The Independent System Operator should set out the blueprint for transmission infrastructure by developing and regularly updating a strategic spatial energy plan, as recommended by the Electricity Networks Commissioner.¹¹² This should build on recent positive steps in strategic planning,¹¹³ and be developed with oversight from Ofgem.

Strategic planning of the distribution network would also drive benefits. The existing capacity of distribution networks is not well understood, and therefore the level of investment required to meet the future trajectory of demand from low carbon technologies is uncertain. More data on current network usage will support future planning.¹¹⁴ Ofgem's proposal to create Regional System Planners is welcome as this will help support strategic investment decisions.¹¹⁵ The key objective of Regional System Planners should be to deliver this through engagement with, and input from, network operators and local authorities from the outset. This can include using input from existing local area energy plans (Box 2.2).

Box 2.2: The role of local engagement in energy system planning

Local authorities are playing an important role in the delivery of a decarbonised energy system in their regions. Local area energy plans are one of the tools local authorities use to identify viable pathways for decarbonising buildings and industry in their areas.¹¹⁶ These represent a valuable collation of data about the energy needs of an area to meet net zero, capturing local characteristics such as information on the built environment and the industries present. The approach seeks to identify what is needed, where and by when to reduce emissions and then to estimate how much it may cost to deliver. This can, for example, support decision making on electric vehicle charge point locations and where heat networks would be best suited. The information gathered through these plans could be used by Regional System Planners to support efficient network planning and investment decisions.

A lack of investment in network infrastructure has meant getting a connection to the electricity network has now become a barrier to decarbonisation, with delays of over 15 years being reported.¹¹⁷ This prevents the delivery of new electricity generation and storage, as well as delaying the rollout of heat pumps and electric vehicle charge points. Strategic planning of the required network, and ensuring barriers to its delivery are reduced, can go a long way to resolving this. But further intervention is needed to improve the connections process itself. The current first come, first served system is clearly not working. The government, industry and Ofgem are working on a plan. Without decisive action, this will continue to slow the rollout of key technologies that are crucial to meeting decarbonisation targets.

Recommendation 5: Government should reform governance arrangements to enable the transformational change in network infrastructure that will be required to support a decarbonised electricity system, including:

- **completing the setup of the Independent System Operator by the end of 2024, and ensuring it has the duties, tools and access to data necessary to plan and manage interactions between energy vectors**
- **ensuring the Independent System Operator has a duty to develop and maintain a strategic spatial energy plan, with the first version of this plan in place by 2025 and updated regularly**
- **providing strategic clarity to Ofgem through the Strategy and Policy Statement by the end of 2023 on the need for investment in electricity distribution and local flexibility solutions ahead of need that are sufficient to meet the demands of electric vehicles and heat pumps implied by carbon budgets**
- **establishing the Regional System Planners proposed by Ofgem in time to inform the next electricity distribution price control in 2028.**

Increasing resilience

The energy system has proven to be vulnerable to price shocks such as that from Russia's illegal invasion of Ukraine. There is a significant economic cost from global energy price shocks and the UK has not been able to resist and absorb them in the past.¹¹⁸ The scale of the impact on energy prices from Russia's illegal invasion of Ukraine is rare but not a one off. The oil crises of the 1970s also caused energy price shocks of a similar scale.¹¹⁹ Such shocks will happen again. Government has acted in other markets to insure against high impact low probability events and should do the same for energy.¹²⁰

Delivering a highly renewable system will go a long way to protecting the economy from energy price shocks in the future. To further reduce the impact of such shocks, government should establish a strategic energy reserve to provide resilience to infrequent but high impact energy price shocks. The reserve would be drawn on only for rare events causing global price shocks that would result in material economic cost. This would in time replace the existing oil reserve set up in response to the oil crises of the 1970s.

There should be ministerial control over when the reserve would be used. To ensure the reserve is available when needed, monitoring storage facilities' compliance will be important. The store of energy should be in the form of hydrogen in the long term, although until hydrogen fired generation is deployed at scale it may be prudent to store natural gas. The store should be built up over time to minimise the cost of procurement. Storing hydrogen equivalent to around 60 days of non-renewable electricity generation would be in line with comparable reserves of other fuels.¹²¹ By 2040 this equates to a store capable of providing around 25TWh of electricity. This volume accounts for the fact that a significant share of electricity will be provided by domestically generated electricity which will not be impacted by global shocks.

Building in this resilience is likely to reduce the cost of future shocks and is estimated to add around two per cent to the average energy bill. Improving the ability of the system to resist and absorb shocks will be investment well made.¹²² Government should begin planning for this soon — large scale hydrogen storage can take up to ten years to develop.¹²³

Recommendation 6: Government should develop a strategic energy reserve to support resilience to economic shocks. To deliver this, legislation should be introduced to give the Secretary of State powers to establish and control the reserve. Government should take the necessary actions to develop a reserve that can be used to generate 25TWh of electricity in 2040, and then maintain it at this level.

Switching to electrified heat

Heating buildings still accounts for 24 per cent of fossil fuel demand.¹²⁴ The majority of English homes — 88 per cent — are reliant on natural gas for heating.¹²⁵

Around eight million buildings in England (around 30 per cent of the building stock) will need to switch from fossil fuel boilers to heat pumps (or other electric heaters) by 2035,¹²⁶ and all buildings will move away from fossil fuel heating by 2050. Today, only eight per cent of homes

have electric heating.¹²⁷ Similar trajectories will be necessary in the devolved administrations.¹²⁸ These volumes are driven by government's commitment to reducing emissions from buildings by around 50 per cent by the mid 2030s and to close to zero by 2050,¹²⁹ although doing so will bring other benefits. Reducing households' and businesses' reliance on fossil fuel heating will improve air quality and permanently reduce heating costs.

Encouraging this many households and businesses to switch to heat pumps is challenging but achievable. Most households on gas boilers have not yet considered switching to other forms of heating.¹³⁰ Government should provide additional incentives that support households and businesses make the switch. This is not the first time the way homes are heated has had to change. In the 1960s and 70s, all gas appliances were converted from town gas to natural gas in ten years (Box 2.4).¹³¹ And this would not be the first time that government has directly supported upgrades to housing. A move to indoor plumbing started in the 1940s with support from government and by the 1970s and 80s grants covered most of the cost.¹³²

A lack of clear information, confusion over what the options are, higher upfront costs and fear of higher running costs all disincentivise switching away from fossil fuel heating.¹³³ Government actions should address these barriers and match the scale of the challenge and the pace of change required by:

- supporting households and businesses to reduce their energy demand
- funding the transition across the public and social housing sectors and for households on lower incomes
- improving the incentives for small businesses, owner occupiers and landlords to switch
- taking a decision on hydrogen's role in heating
- planning for phasing out fossil fuel heating options.

Heat pumps are the most efficient way to heat buildings

Heat pumps should be the dominant electrified heating solution. They are highly efficient, available now and are deploying rapidly in other countries. For every unit of energy paid for, a heat pump can generate around three units of heat (by 'pumping' heat from outside into the house), whereas a fossil fuel boiler generates less than one unit of heat per unit of energy paid for.¹³⁴

There is growing evidence that heat pumps are suitable in a wide range of building types.¹³⁵ The government has stated that 90 per cent of homes already have sufficient energy efficiency and internal electrical connection capacity to accommodate a heat pump.¹³⁶ This aligns with evidence that buildings with an energy efficiency rating (EPC) D or above, which make up 90 per cent of English homes,¹³⁷ are likely to have a peak heat loss rate that makes them suitable for heat pumps with minimal to no energy efficiency improvements. Peak heat loss rate is important as it impacts the effectiveness of a heat pump. In the share of the ten per cent of homes which would need at least some energy efficiency improvements, there will be a proportion where these improvements could be costly. Installing high temperature heat pumps could be more cost effective for these homes than carrying out extensive energy efficiency improvements.¹³⁸

Heat pumps will be challenging to install in space constrained buildings. The most common heat pump systems require a hot water tank which requires space. Around ten per cent of English homes may not have space to add a hot water tank.¹³⁹ However, other forms of thermal storage, like heat batteries, that take up less space, could be combined with a heat pump, and innovation continues to bring new options to the market.¹⁴⁰

In a small proportion of buildings, other electric heating options may be more suitable. Heat networks that run from heat pumps that draw heat from the air, the ground, or even other sources like rivers, are options for blocks of flats, serving multiple occupants. District heat networks can also connect multiple buildings. For other buildings, various forms of direct electric heating, like storage heaters, could also be used, and already are in many buildings, particularly in city centres.¹⁴¹

Improving efficiency will reduce energy demand

Government's ambition is to reduce energy demand from buildings and industry by 15 per cent (from 2021 levels) by 2030.¹⁴² New policies are needed to deliver government's ambition, reduce energy bills by reducing the energy used to heat buildings, and to alleviate the broader consequences of ill health caused by cold homes, including the burden this has on the NHS.¹⁴³ Improving energy efficiency will also reduce the demands on the energy system.

Energy efficiency improvements are likely to be needed in a small proportion of buildings to make running a heat pump more effective. It is important that, where households do want to improve the energy efficiency of their homes, they are encouraged to do so, given the knock on benefits in reducing the amount of energy needed. Government should encourage the installation of energy efficiency measures through zero interest loans, helping to pave the way for heat pump deployment.

Households on lower incomes, those in vulnerable circumstances and those with protected characteristics (which mean their energy demand is higher than average) could stand to benefit the most from improved energy efficiency but are also least likely to be able to afford it. Financial support for improving energy efficiency targeted at lower income households, including those living in social housing, can support these groups.¹⁴⁴ To deliver this, government should extend existing support mechanisms, such as the Energy Company Obligation¹⁴⁵ (which requires energy companies to deliver improvements to the least energy efficient homes and targets lower incomes) and the Social Housing Decarbonisation Fund,¹⁴⁶ and outline a plan for tightening regulations for the private rented sector.¹⁴⁷ In relation to budgets for social housing improvements, delivery of devolved multiyear funding packages to local authorities to support social housing providers in their area should be used rather than the existing approach of competitions for available funds.

Recommendation 7: Government should reduce energy demand from buildings by:

- **extending the Social Housing Decarbonisation Fund to deliver £5.1 billion of capital spending on energy efficiency improvements between 2024 and 2030 and devolve directly to local authorities to deliver the programme**
- **continuing the obligation on energy companies to install energy efficiency improvements in households on lower incomes, delivering £8.8 billion of capital spending between 2024 and 2035**
- **providing zero per cent financing for households and small businesses for the cost of energy efficiency installations**
- **setting out, by the end of 2025, a plan to tighten and enforce minimum standards in the private rented sector.**

Long term funding to deliver heat decarbonisation

Government will be responsible for funding the decarbonisation of the public sector estate. To ensure the transition can be delivered, it should also fund the transition for all social housing and households on lower incomes.

Government, both central and local, is directly responsible for parts of the social housing building stock. Even for housing associations, the costs of switching heating systems would be hard to recover from social rents. Government will therefore need to fully fund the switch in all social housing to ensure it happens. As with funding to improve energy efficiency, long term budgets should be devolved.

Government has committed to reducing emissions from the public sector by 75 per cent (from 2017 levels) by 2037.¹⁴⁸ Government now needs a programme that can effectively deliver this commitment. This should involve long term devolved budgets for departments and local government to decarbonise the parts of the estate they are responsible for rather than the current approach of competitive bidding processes for funding individual schemes. Public sector decarbonisation also presents an opportunity to modernise schools, hospitals and other buildings, improving ventilation, offering resilience to hotter weather and ultimately lowering bills.

Finally, households on lower incomes are unlikely to be able to fund heat pump installations. Without support, these households are likely to stay on fossil fuel boilers for longer which will cost them more to run. To avoid this, and to support decarbonisation targets being met, the Commission recommends directly funding the installation of heat pumps or connection to a heat network for households on lower incomes which, based on the threshold applied in existing support schemes, equates to roughly the bottom 30 per cent of incomes.¹⁴⁹

Making these long term commitments will also help build the market for low carbon heat installations. It will build up supply chains, giving businesses confidence to invest in the skills that will be needed for installations and maintenance.¹⁵⁰ Delivering this will support a programme of jobs across the nation for 30 years.¹⁵¹ These actions will in turn make installations cheaper for other households and businesses in the future.

Recommendation 8: Government must commit long term funding to deliver low carbon heat across the public sector estate, social housing and for households on lower incomes by:

- **allocating £28.9 billion between 2024 and 2050 to deliver low carbon heat and energy efficiency improvements in the public sector estate, including across devolved administrations, and 75 per cent of this funding should be committed to 2035**
- **allocating £33.8 billion between 2024 and 2050 to deliver low carbon heat in the social housing sector, and devolve funding to deliver the programme, and 35 per cent of this funding should be committed to 2035**
- **allocating £41.7 billion between 2024 and 2050 to deliver low carbon heat to all other households on lower incomes, and 35 per cent of this funding should be committed to 2035.**

Incentives to switch to low carbon heating can be strengthened

While government support should be prioritised for those households least able to afford it, as set out above, there should also be policy changes put in place to encourage all households, building owners and small businesses to make the switch. There will be many that cannot afford the upfront costs of switching to a heat pump or cannot access finance at a reasonable cost, even after any subsidies. This will delay the transition to a decarbonised heating system. For the switch to low carbon heat to be acceptable the current gap in lifetime costs between a heat pump and a gas boiler must be closed.

Heat pump installations in existing properties need to grow by an average of 35 per cent each year to switch seven million existing fossil fuel heating systems to heat pumps or heat networks by 2035 and therefore achieve the government's emissions reduction target.¹⁵² The growth rate in switches to heat pumps in 2022 was 14 per cent, down from a peak in 2021 of 51 per cent.¹⁵³ Achieving this growth rate is challenging, but it is achievable, and similar rates have been seen in other countries (see Figure 2.2).

Box 2.3: International market for heat pumps

Other countries have successfully accelerated heat pump uptake through a combination of government policies and incentives. This has included subsidies or tax rebates for installations, low cost loans, bans on new connections to the gas network, building standards and favourable electricity prices. Between 2018 and 2021 the Netherlands and France have each seen average year on year growth of 27 per cent. Average growth in Poland has been 48 per cent, with a high of 61 per cent year on year growth in 2021.¹⁵⁴

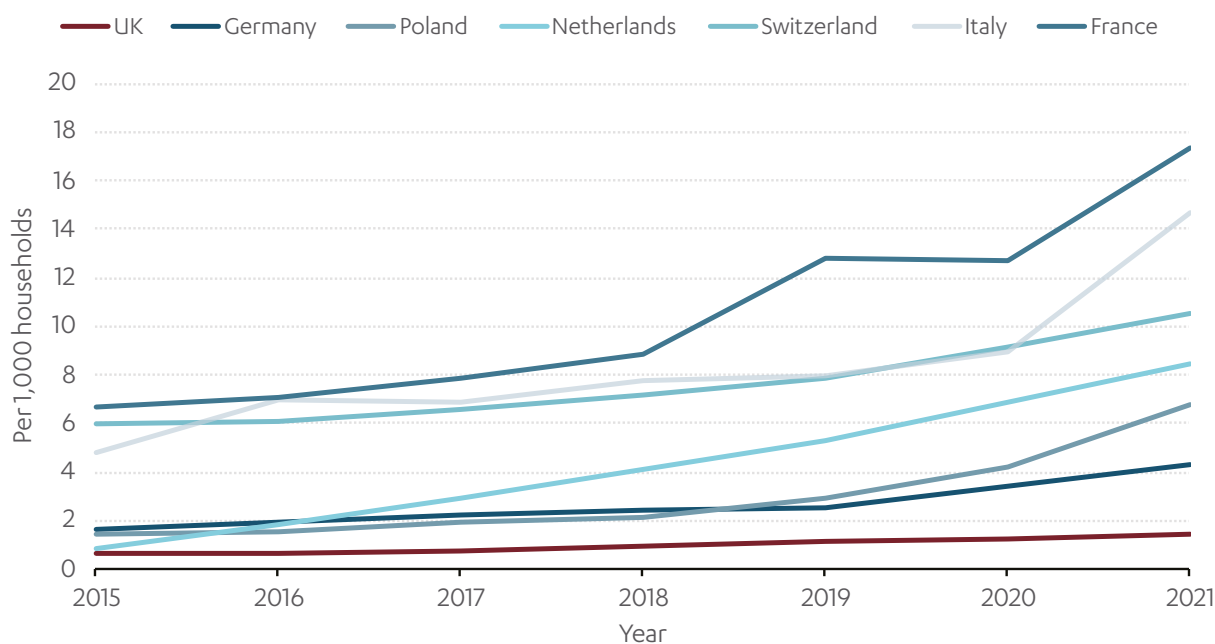
In the **Netherlands** there are low interest loans as well as a grant for heat pumps. The grant runs up to 2030 providing long term certainty to households and businesses. There has also been a ban on new connections to the gas network since 2018 and new fossil fuel boilers will be banned in 2026.¹⁵⁵

In **France** a mixture of grants and zero interest loans are available to households for heat pumps and energy efficiency. New gas connections and replacement oil boilers were banned in 2022.¹⁵⁶

In **Poland** there are aims to move away from coal fired heating in cities by 2030 and in rural areas by 2040 with policies including grants, tax relief and loans for heat pumps.¹⁵⁷

Figure 2.2: Policy has driven substantial growth in heat pump sales in other countries

Total heat pump installations on new and existing buildings per 1,000 households



Source: Commission analysis of European Heat Pump Association (2022), European Heat Pump Market and Statistics Report 2022

Government should seek to encourage the uptake of heat pumps through:

- increasing the overall subsidy available
- providing zero per cent financing to all households and small businesses for the remaining cost of a heat pump installation
- rebalancing gas and electricity prices
- alleviating barriers to delivery of a smooth consumer experience.

Heat pump uptake can grow rapidly if the upfront cost, which on average could amount to around £10,000 more than a gas boiler, is reduced.¹⁵⁸ Research points to the upfront cost being the main barrier to take up.¹⁵⁹

To achieve this, the subsidy available for heat pumps should be around £7,000 to make them cost competitive with alternatives. This subsidy should encourage take up, grow the market in the near term and drive cost reductions. As cost reductions are realised, the government subsidy can be reduced. However, some degree of subsidy will likely be necessary until 2050 to deliver a low carbon heat solution to all buildings.

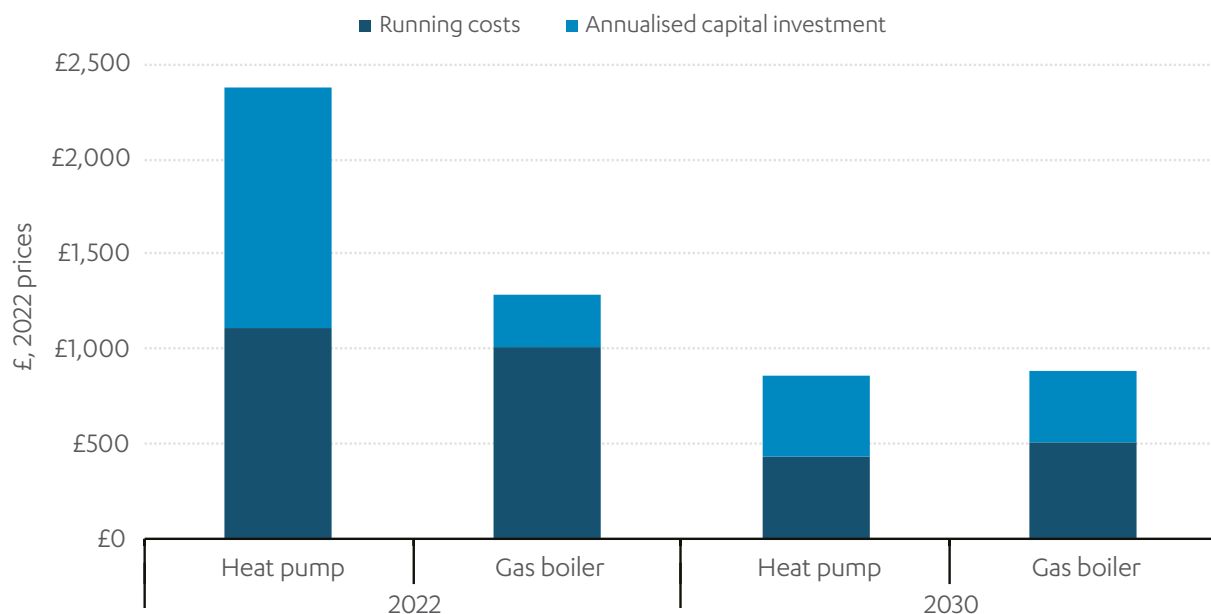
Increasing the subsidy will still leave most households, building owners and small businesses needing to pay roughly half the cost of a heat pump installation (based on current average costs). There will be many that do not have access to savings to cover this additional upfront cost and cannot access financing at a reasonable rate. Access to zero per cent financing, backed by government, will lower this barrier, and should enable more households to switch.¹⁶⁰

While upfront costs are the main barrier, it will also be crucial that the running costs of a heat pump are lower than a gas boiler. Heat pumps use less energy than gas boilers, but they have typically been more expensive to run due to differences in the gas and electricity prices. Electrified heating has traditionally been more expensive because the electricity price includes the cost of policies that do not apply to gas. Although in 2022 gas prices increased more than electricity prices which narrowed the gap.¹⁶¹

Government has committed to rebalance the cost of electricity and gas. To deliver on this commitment, it should fund policies for decarbonising the electricity system through general taxation rather than through electricity bills. This should ensure that the cost of running a heat pump is cheaper than running a gas boiler (Figure 2.3). It should also be prepared to make further interventions, if necessary. The price of gas is dependent on the wholesale cost which fluctuates, and future gas prices may also be impacted by declining use of the network. Any interventions that push up the price of gas could have distributional consequences which should be evaluated ahead of implementation and negative impacts should be addressed, for example through establishing a social tariff.¹⁶²

Figure 2.3: The Commission's recommendations remove the cost disincentive of installing a heat pump

Energy expenditure of a typical household on a gas boiler vs a heat pump now and in 2030 once policies are established



Source: Commission analysis

Analysis suggests that an initial subsidy of £7,000, zero per cent financing for the additional costs and the government's proposed clean heat market mechanism,¹⁶³ coupled with savings from running costs, are all needed to deliver price parity between a heat pump and a gas boiler on a lifetime basis (Figure 2.3). The clean heat market mechanism will support the transition to heat pumps, but it will not be adequate on its own because of the size of the gap in price between a heat pump and a gas boiler. The Commission's recommended package of incentives plus this mechanism can accelerate the pace of switching. The recommended starting value of the subsidy is marginally lower than that announced by the government in September 2023,¹⁶⁴ but is set in the context of a broader package of incentives and will require a higher overall funding package than the existing Boiler Upgrade Scheme.¹⁶⁵

Other non price barriers stand in the way of consumers switching to heat pumps. These should be reduced by:

- alleviating planning permission restrictions on the location of heat pumps by amending the Town and Country Planning Act Schedule 2, for example to change the rule that all parts of the heat pump must be at least one meter from the property boundary¹⁶⁶
- standardising when installing a heat pump requires approval from the electricity distribution network operator, and when installers can upgrade a house's fuse
- considering changes to permissions and access rules, e.g. loosening restrictions on installing heat pumps in listed buildings, reducing restrictions on what leaseholders can do and granting wayleaves for hot water pipes to support heat network rollout
- improving consumer awareness of the need to transition to low carbon heat and the changes needed.¹⁶⁷

Consumer protection from inadequate information, unfair treatment and poor working practices also needs to keep pace with the developing market.¹⁶⁸

For some buildings, low carbon heat networks will be the best option, rather than individual heat pumps. Heat networks should not be put at a disadvantage. The same amount of subsidy per household or small business should be made available for developing heat networks, via the current Green Heat Network Fund capital grant or similar.¹⁶⁹

Local government will have a critical role in ensuring the transition is delivered efficiently. They will know their area, buildings and residents better than central government and will be able to support delivery of the infrastructure needed. Locally developed plans can help identify areas suitable for heat networks. And they should be able to coordinate any works that need to be done to gas or electricity infrastructure, to minimise disruption.

Recommendation 9: To support seven million buildings in England to switch from fossil fuel heating to a heat pump or heat network by 2035, government should incentivise building owners, including private landlords by:

- **providing a subsidy of £7,000 per property owner for installing a heat pump or connecting to a heat network from 2024, with information published on how this subsidy will reduce over time as take up increases and installation costs fall**
- **providing zero per cent financing for the upfront costs above the subsidy**
- **taking policy costs off electricity bills and ensuring the cost of running a heat pump is lower than the cost of running a fossil fuel boiler**
- **making the process of installing a heat pump or low carbon heat network as fast and simple as possible.**

Hydrogen's role in heating

Hydrogen heating has been proposed as an option to provide low carbon heat. It would use a gas style boiler and would require low carbon hydrogen to be produced in large quantities and be delivered via a network of pipes to buildings. Hydrogen is low carbon when produced via electrolysis, or through reforming natural gas if the carbon emitted in the process is captured and stored. Government has said it will decide on hydrogen's role in heating in 2026.¹⁷⁰

Hydrogen heating will not be available in time to make a material contribution to the Sixth Carbon Budget emissions reduction target. It is reasonable to assume that existing gas networks can be converted to deliver hydrogen to buildings, but it will require a managed programme of area by area switching and this will take time to deliver. The other critical barrier to its use at scale ahead of the mid 2030s is the ability to produce enough of it. Low carbon hydrogen production is currently close to zero.¹⁷¹ In the near term the volume of hydrogen produced via electrolysis will be limited by competing demands for the electricity available (and competing demands for the hydrogen produced) and production through reforming natural gas requires a carbon capture and storage network that is not yet in place, though due to start operating in the 2020s.

All buildings have an alternative to hydrogen heating so it is not necessary. The question is therefore whether there is value in hydrogen heating being part of the low carbon heating mix in the medium to long term. Safety will need to be ensured. A decision on this is for the Health and Safety Executive. If hydrogen heating is assessed as safe, government must then decide how much support, if any, it should provide alongside support for heat pumps and heat networks. This decision should be based on an assessment of the evidence of whether there are public policy reasons for supporting the development of hydrogen for heat.

The Commission has assessed the public policy case across a set of criteria (Figure 2.4). For the case for supporting hydrogen for heat to be made, the system would need to either: rate somewhat better than systems with no hydrogen heating across most (or all) criterion; or rate strongly better than systems with no hydrogen heating on one or more criterion, with no counterbalancing areas where systems with hydrogen heating rate negatively.

Based on the Commission's assessment of the evidence, there is no public policy case for hydrogen to be used to heat individual homes or other buildings. Government should therefore rule out supporting its deployment. A more detailed description of the evidence, methodology and sensitivity analysis used to reach this conclusion is provided in a technical annex.¹⁷²

Figure 2.4: There is no public policy case for hydrogen heating

Criteria and summary of the assessment of hydrogen's role in heating

Criterion	Commission's assessment
Price	Negative Energy system costs are lower without hydrogen heating. The cost of producing hydrogen is forecast to outweigh the greater in-building capital costs of heat pumps.
Quality	Neutral - No discernible difference in the quality of heat provided. - Hydrogen heating requires fewer in-building changes. - Continuity of service is a greater risk for hydrogen heating (initially and on an ongoing basis).
Delivery	Negative - The challenges of delivering a larger and decarbonised electricity system exist in all pathways. - Coordination challenges are greater in pathways with hydrogen heating due to the need for large numbers of properties to disconnect from natural gas and reconnect to a hydrogen supply at the same time. - Supply chain issues could arise in all pathways. For pathways without hydrogen, supply chains for equipment will be global and competition may affect access and price. For pathways with hydrogen heating, supply chains for hydrogen boilers are likely to be UK specific and could face thin market constraints.
Environment	Negative More adverse environmental impacts with hydrogen heating from both indirect greenhouse gas emissions (hydrogen leakage) and emissions of nitrogen oxides.
Resilience	Negative - Resilience to shocks to the electricity system does not differ. Both pathways require electricity to function and the same resilience standards can be set for all systems. - Exposure to volatile natural gas markets could be higher with hydrogen heating, if additional natural gas is required to produce hydrogen or to produce the additional electricity needed. - Geopolitical energy security risks would likely reduce in all pathways as reliance on fossil fuels overall decreases.
Economy	Neutral The benefit to the UK is likely to be similar in all pathways as the proportion of economy activity that is UK based is broadly similar.

Source: Commission analysis

Under the price criterion, a comparison is made of the cost of the whole energy system – electricity and hydrogen generation, electricity and hydrogen networks, storage and in-home appliances – between scenarios with hydrogen heating and without.

Using electricity to produce hydrogen to then use in boilers to produce heat requires five to six times more electricity than using the same electricity directly in a heat pump.¹⁷³ This is because more energy is lost in converting electricity to hydrogen, and heat pumps use less energy than boilers to produce the same level of heat. However, this does not result in a whole energy system with hydrogen heating being five times more expensive once all costs, efficiencies and interactions are accounted for. The Commission's analysis takes into account the interaction between choices in different parts of the system, namely:

- heat pumps use around three times less energy than hydrogen boilers to produce heat but have higher upfront in-building installation costs
- hydrogen heating reduces the direct use of electricity and peak electricity demand from heating but increases overall demand because electricity is used to produce hydrogen
- electricity demand for hydrogen production through electrolysis will affect the unit cost of electricity and the availability of 'spare' (i.e. curtailed) electricity will impact the cost of hydrogen production
- hydrogen heating requires a more extensive system of hydrogen pipelines and additional storage, but no hydrogen heating requires more decommissioning of the natural gas network.

The Commission's analysis estimates that a system with hydrogen heating would be around 1.2 times more expensive than a system without.¹⁷⁴ These results are based on some assumptions, for example about future price of fuels and the extent of hydrogen heating, but the result holds true under a range of reasonable variations to these assumptions.

Delivering decarbonised heat will be a challenge under all scenarios. But there are unique challenges in scenarios with hydrogen heating that make it a worse option. The process of switching buildings from a natural gas to a hydrogen supply must happen at the same time for multiple buildings. Already having a hydrogen compatible boiler will not alleviate the need for this coordinated approach which will require simultaneous entry into every building in an area that is switching supply.

The town gas transition in the 1960s and 1970s required a similar approach (Box 2.4). However, the challenge may be greater today because the industry is structured differently, there are more buildings connected to the gas network and social changes mean people are less likely to be at home to provide access to their property.¹⁷⁵

All scenarios must meet carbon budgets and the net zero target. But hydrogen heating increases the volume of hydrogen used in the economy and the length of network needed to transport it. This increases the potential for leakage in comparison to scenarios with no hydrogen heating, though it is expected that leakage would be managed down to low levels. Scenarios with hydrogen heating also produce more nitrogen oxide emissions when hydrogen is combusted in boilers. It is expected that appliance design standards and regulation will be able to ensure these emissions are equal to, or below, the levels produced by gas appliances today, but electric heating carries no risk.¹⁷⁶

A decision by government not to support hydrogen for heating still leaves open the potential for commercial development of networks to provide hydrogen heating to consumers who want it. However, this will only happen if it proves commercially viable.

A national effort is needed to scale up the supply chain and deploy heat pumps, which are available now and suitable for most buildings. Keeping the option of hydrogen heating on the table could cause confusion and further delay heat decarbonisation.

Recommendation 10: Government should not support the rollout of hydrogen heating. Infrastructure solely for hydrogen heating should not be eligible for support under the hydrogen transport business model and today's gas users should not be expected to pay for the conversion of natural gas infrastructure to transport hydrogen through existing price controls.

Fossil fuel heating should be phased out

Alongside incentivising switching, to meet the net zero commitment government should put in place backstops to ensure no buildings are using fossil fuel heating by 2050. The public need to see from government a long term pathway that provides them with support for switching away from fossil fuel heating.¹⁷⁷ A plan, timely decisions and clear communication in advance are needed to ensure a smooth transition.

To phase out fossil fuel heat, firstly, government should not allow new buildings to connect to the gas network. Households and businesses should not be locked into options that have a finite life.¹⁷⁸ Government should also use regulation to end the use of fossil fuel heating in some sectors in the near term. Large commercial buildings (those over 1,000m²) account for around ten per cent of emissions from buildings, despite making up less than one per cent of the building stock.¹⁷⁹ Targeting regulation at this sector, which is most likely to be able to respond and take advantage of the changing relative prices of gas and electricity, would mean fewer buildings will need to switch in other parts of the building stock which are more challenging to decarbonise.¹⁸⁰

Government has an ambition to start phasing out the sale of new fossil fuel boilers by 2035.¹⁸¹ The Commission recommends that from 2035 no new fossil fuel boilers are sold. This will provide clarity to households and certainty to businesses that will be investing in low carbon heating technologies and the workforce needed to install them. A strong commitment to this date, ensuring that it does not slip back, should help drive take up of heat pumps and limit the number of households and businesses that have to change working fossil fuel boilers in 2050 when they will no longer be served by a gas supply in order to meet government's net zero commitment.¹⁸² Government has been successful in driving the transition to electric vehicles and can apply the same approach to setting long term policy to support the heat transition. In driving the switch to electric vehicles, it:

- signalled an end date for the sale of new petrol and diesel cars and vans well in advance¹⁸³
- led the way in decarbonising its own fleet of vehicles¹⁸⁴
- established policy to build the supply chain¹⁸⁵
- provided financial support and other incentives including for charging infrastructure.¹⁸⁶

A transition away from gas heating means buildings will need to be disconnected from the gas distribution network, which, in turn, will need to be safely decommissioned unless an alternative use can be found. The process will be complex and there are many detailed aspects to be worked through. Lessons can be taken from the transition to town gas (Box 2.4).

Box 2.4: Learning lessons from the town gas conversion

Following the discovery of natural gas in the North Sea in 1965, there was a programme to convert buildings from town gas (made from coal or oil) to natural gas. In the decade between 1967 and 1977 around 14 million buildings and 40 million appliances were converted.¹⁸⁷ This was a significant logistical challenge, involving coordination between a range of actors, including regional gas boards, industry, contractors and the public. Government had a central role in both coordination and delivery, via the nationalised gas boards. It provided top down coordination of both the physical conversion programme and public relations campaigns.

The scale and complexity of the programme meant government coordination was necessary. Entire neighbourhoods needed to be converted at the same time in order to not leave houses without heating, and there were other challenges around supply chain capacity and skills that government took an active role in addressing. Coordination and public engagement led to the town gas conversion being seen as a success.¹⁸⁸

Government should establish a national plan for disconnecting properties from the gas network. Signalling the timetable and preparation will be key to a smoother transition for households and businesses. Biogas producers connected to the gas network will also be impacted by the declining use of the gas network and need more information in order to better understand and plan.

A disconnection and decommissioning plan should provide clarity on the roles of government (at both national and devolved level), local government, Ofgem, the Health and Safety Executive, energy system planners and network operators. Electricity network operators will need to ensure their networks can cope with the increase in demand the transition will drive. And gas network operators will need to ensure the continued safety of their network for remaining customers and play a significant role in the disconnection and decommissioning process.

A blend of national and local management of this process will be essential to limit the risk of negative impacts. Government should set national targets aligned with emissions reduction targets. But switching off the supply of gas will require an area by area approach.¹⁸⁹ Local government should therefore play a central role by:

- providing democratic input to decisions made about the sequencing of gas disconnections
- scrutinising the input into these decisions from the gas and electricity network operators who will be the bodies that deliver the infrastructure changes that are needed, with the support of the proposed Regional System Planners¹⁹⁰
- playing a role in protecting households and businesses, particularly those in vulnerable circumstances, through the transition.

The economics of running and using the gas network for home heating will become more challenging as more households switch to electrified heating. There will be regulatory impacts to be addressed in facilitating the continued operation of the network until the last remaining customer is disconnected and in considering how decommissioning costs are recovered.

Recommendation 11: Government should plan for the end of the use of natural gas for heat by:

- **banning new connections to the gas network from 2025**
- **regulating, by 2025, to end the use of fossil fuel heating in commercial buildings over 1,000m² by 2035**
- **ending the sale of all new fossil fuel boilers in 2035**
- **making provisions for the process of disconnecting customers and decommissioning, or repurposing, the gas network**
- **establishing a mechanism for local democratic input into decommissioning plans**
- **working with Ofgem and the Health and Safety Executive on a plan to ensure the switch is safe and efficient and that consumers in vulnerable circumstances are protected.**

Rolling out electric vehicles

Surface transport remains too carbon intensive, accounting for 26 per cent of fossil fuel demand.¹⁹¹ Road transport accounts for around 98 per cent of surface transport emissions.¹⁹² The transition of the fleet to zero emission electric vehicles is therefore crucial for decarbonising the transport sector.¹⁹³ Zero emission vehicles also deliver better air quality and reduce noise pollution.¹⁹⁴ They are also more efficient and typically cheaper to run.¹⁹⁵ Their upfront, maintenance and running costs are expected to reach parity with petrol and diesel cars in the next ten years.¹⁹⁶

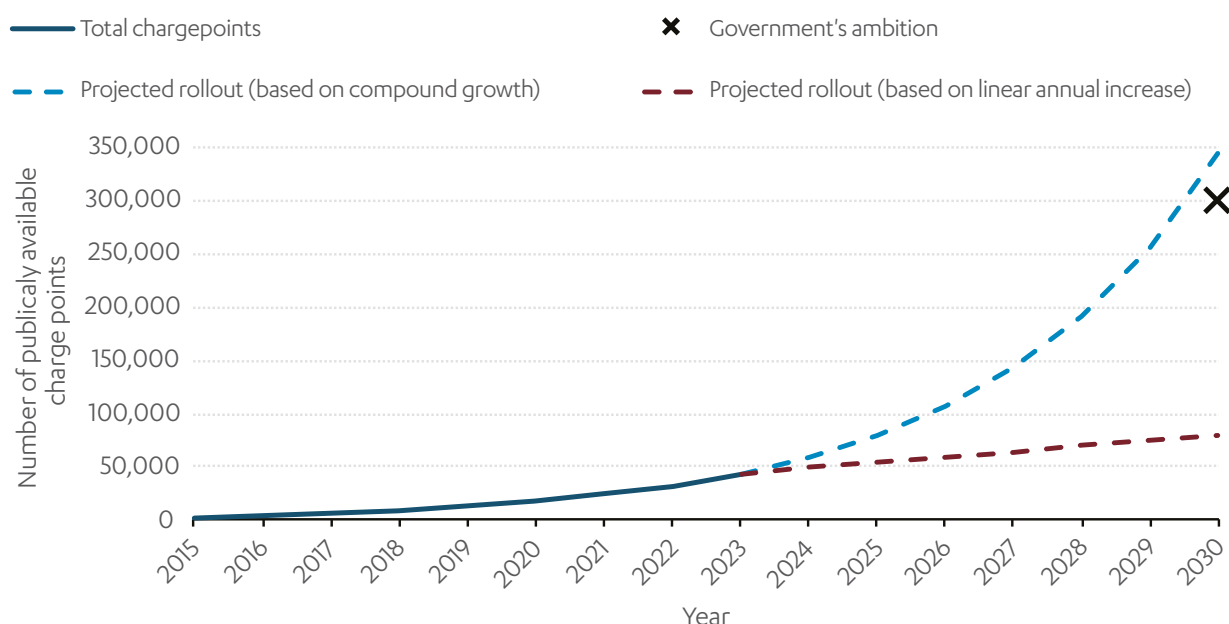
Deploying electric vehicles

For consumers to switch to electric vehicles, they need to be sure that they will have adequate access to charging infrastructure. The government expectation of 300,000 public chargers being available by 2030 should deliver this.¹⁹⁷ Access to public charge points is particularly important as many drivers will not be able to charge their vehicles at home.¹⁹⁸

Access is increasing. As of August 2023, there were around 45,500 public charge points in the UK, of which 8,700 were rapid,¹⁹⁹ and year on year growth was 38 per cent.²⁰⁰ To meet the government's expectation, the number of public charge points installed annually must continue to grow at around 30 per cent per year. If deployment only increases linearly by the same volume as in recent years, deployment will fall well short (Figure 2.5). Maintaining 30 per cent year on year growth will become more challenging in later years. For example, in 2029, roughly 75,000 charge points will need to be deployed — more than eight times as many as in 2022.

Figure 2.5: Charge point deployment will have to grow at 30 per cent each year to meet the government's targets

Publicly available electric vehicle charge point rollout, 2015 to 2030, UK



Source: Department for Transport (2023), Electric vehicle charging device statistics (July 2023)

Note: Annual charge point total is based on data from July of each year.

Government progress to date includes it setting out its plans to achieve the acceleration of charging infrastructure deployment. This includes funding for rapid charging on motorways and A-roads, and increased funding to support local authorities to deploy public charge points.²⁰¹ Growing demand for electric vehicles should make charge point deployment more commercially attractive, incentivising the private sector to deliver.²⁰² Ofgem has also reduced connection charges associated with installations, removing a barrier to deployment.²⁰³ However, other barriers to deployment remain, such as issues in securing timely connection to the electricity network due to capacity limitations and slow progress in creating more capacity.²⁰⁴ With less than seven years left to meet its target, government and Ofgem must address these barriers to deployment.

Moreover, to ensure zero emission vehicle take up is viable, charge point provision must be spread across the country — in rural areas, towns and cities — to support journeys of all types. Drivers want charge points to be easily accessible.²⁰⁵ So the location of charge points is as important as total numbers. Local authorities are ideally positioned to identify local charging needs and should play a more active role in facilitating private sector investment in the deployment of public charging infrastructure.²⁰⁶ Local authorities are responsible for parking and street furniture where on street charging is often installed. The Geospatial Commission has published advice on how local authorities can use location data and geospatial applications to inform decisions.²⁰⁷ To perform this role effectively, local authorities should be sufficiently equipped and supported.

Recommendation 12: Government must accelerate deployment of electric vehicle public charge points to reach its expectation of 300,000 public charge points by 2030 and keep pace with sales of electric vehicles.

Adaptive plans for transport decarbonisation

The government's main policy to drive the transition to electric vehicles is the zero emission vehicle mandate. This policy, underpinned by adequate provision of charging infrastructure, is likely to substantially reduce emissions from surface transport.²⁰⁸ The proposed mandate will regulate manufacturers so that:

- 80 per cent of new car sales are zero emission by 2030 and 100 per cent by 2035
- 70 per cent of new van sales are zero emission by 2030 and 100 per cent by 2035.

In 2030, the remaining 20 per cent of new car sales and 30 per cent of new van sales are now expected to be a mix of hybrid and purely petrol or diesel cars,²⁰⁹ rather than just hybrid as initially proposed.²¹⁰ It is important that the share of petrol and diesel cars in the fleet reduces as quickly as possible to maximise the number of cars capable of driving on electric mode.

Sales of zero emission cars are ahead of expectations. But take up of electric vans is currently slower than anticipated.²¹¹

The Commission's review of the government's decarbonisation plans highlights uncertainties in delivery of desired emissions reductions. There is uncertainty in the speed of the transition of the car and van stock to zero emission vehicles, the fuel efficiency of the remaining petrol, diesel and hybrid vehicles and future traffic demand.²¹² These uncertainties will be impacted by developments in automotive markets, potential innovations in vehicle efficiency, evolving policy plans and consumer behaviour.

Government should recognise this uncertainty by establishing an annual monitoring and review regime to assess progress against its decarbonisation targets. This regime should ensure actions in place remain adequate to deliver decarbonisation at the pace needed. Key indicators should be identified – for example, zero emission vehicle take up, fuel efficiency and future traffic demand. Appropriate target ranges and trigger points should be established based on up to date data.

The monitoring regime should enable government to identify and respond to any emerging shortfalls in meeting emissions targets. Waiting five years before reviewing, as set out in the Carbon Budget Delivery Plan, is not frequent enough to allow for policy approaches to be adapted.²¹³ Government should be transparent in the approach it takes to the review by publishing data and its assessment. The government is already required to demonstrate that any road enhancements are compatible with net zero before investing,²¹⁴ so publishing this data would also support this aim.

Alongside this, as part of the work preparing an integrated interurban transport strategy (discussed in Chapter 3), government should prepare adaptive measures to reduce emissions from road transport, to be deployed if required. Potential measures should be plausible and carefully designed to address distributional issues and value for money.

The overall focus of decarbonisation plans should also be reviewed over time. For example, as emissions from cars reduce, the decarbonisation of freight will become relatively more important for reducing road transport emissions, through the increased adoption of battery electric or hydrogen heavy goods vehicles. As the focus of government's plans shifts, so should its monitoring and review regime.

Recommendation 13: Government should, by 2025, establish a monitoring and review regime for its transport decarbonisation plans that reflects the uncertainty in carbon emissions outcomes from surface transport. The need for action to ensure decarbonisation targets are met should be reviewed annually, and all relevant information made publicly available. Carefully designed, adaptive policies that can be introduced, if necessary, should be prepared as part of the work on the integrated transport strategy.

New networks to support a thriving economy

Around ten per cent of fossil fuel demand across the economy is driven by industry.²¹⁵ The trajectory government has set to reduce emissions requires a 70 per cent reduction by the mid 2030s.²¹⁶ These fossil fuels will need to be replaced by, predominantly, electricity or hydrogen or abated using carbon capture and storage. Where electrification is feasible it should be pursued as a lower cost solution. However, there is broad consensus that a mix of all three is needed.²¹⁷

To enable this, new hydrogen and carbon capture and storage infrastructure will be needed. This infrastructure will also be essential for delivering a flexible decarbonised electricity system (as set out earlier in this chapter) and carbon capture and storage will, additionally, be key to facilitating engineered greenhouse gas removals.

Options for how to decarbonise means there is uncertainty in the level of demand that will arise for hydrogen and carbon capture and storage infrastructure. Government can both provide incentives for industry to decarbonise and ensure options are available through coordinating delivery of shared infrastructure.

For both hydrogen and carbon capture and storage networks, planned placement of new networks should support existing industries and encourage new industry into areas which have seen decline, such as north east Scotland, and the north east and north west of England and Wales (see Figure 2.6).

Figure 2.6: Core networks for hydrogen and carbon capture and storage should focus on major industrial hubs first

Industrial point source emissions by area (MtCO₂e), 2020

Cluster location	Industrial point source emissions (MtCO ₂ e)	Cumulative per cent of industrial point source emissions
Humberside	8.9	18%
South Wales	6.4	31%
Merseyside	4.5	41%
Grangemouth	4.1	49%
Teesside	3.4	56%
Southampton	3.0	62%
Peak District	2.9	68%

Source: Commission analysis of National Atmospheric Emissions Inventory (2020), Emissions from NAEI large point sources

Incentivising the switch to low carbon energy

Building hydrogen and carbon capture and storage networks will be crucial to enabling the switch away from fossil fuels to low carbon alternatives. But industry will not make the switch without policies to encourage them to do so. Government has some policies in place to support innovation and drive switching but a comprehensive strategy is needed.

This strategy will need to include a range of policies. Carbon pricing, regulation and incentives can all act to support industry switch from high carbon fuel sources to low carbon ones and deliver on government's ambition.

Recommendation 14: Government should ensure policy actively encourages industrial decarbonisation at the speed needed to hit its carbon budgets through a mix of carbon pricing, other incentives, regulation and shifting public procurement to low carbon products.

Developing core networks

Future demand for hydrogen and carbon capture and storage is uncertain. But they will be needed to achieve net zero and support the UK's industrial activity as buyers increasingly demand low carbon products.

Policy to support development of infrastructure is not moving forward at the pace needed. Government has started the process of supporting carbon capture and storage infrastructure at four industrial hubs with the aim to have them operational by 2030.²¹⁸ For hydrogen pipelines and storage, government has recently issued an update on its plans, but support arrangements are not set to be agreed until 2025.²¹⁹

Networks that connect multiple producers, users and stores of hydrogen, and emitters and stores of carbon in different parts of the country will provide benefits that would not exist with point to point pipelines. These networks can:

- Provide **resilience** by enabling industrial clusters to access other sources of hydrogen supply or demand, or hydrogen or carbon storage. This will be particularly important in the early years when the number of sites is small, and the impact of disruption could be more significant.
- Help achieve a **single price** for access and use of the network. Having a network means each customer on the network can buy from multiple sellers, and this competition should reduce costs overall, and this reduction in costs will help offset the costs of building a larger network.²²⁰
- Increase **optionality** on where users of the network can be based. For example, it means hydrogen production sites do not need to be based nearby users which frees them up to be located where they will not put pressure on the water supply.²²¹
- Provide access to more **storage** locations, providing more options and more storage capacity, especially for hubs that do not have nearby storage potential.
- Create more opportunities for switching **existing unabated gas fired generation** sites outside of industrial hubs to hydrogen or gas with carbon capture and storage. These sites have the advantage of access to electricity networks and cooling water, which make them feasible to switch.

At present, uncertainty around the scale and location of demand for hydrogen and carbon capture and storage networks mean potential developers of pipelines and stores face a high risk of their assets being underused. The private sector is currently unwilling to take on all this risk alone. Government should therefore provide coordination and support and take on some risk in order for networks to be developed, while acting to reduce demand uncertainty through policies that encourage adoption of low carbon energy sources.

To manage this risk of the network being underused or stranded, government support should focus on core networks, initially serving locations where demand uncertainty is lowest. These core networks should also be designed to support industries to transition to low carbon products and maximise the opportunity to deliver decarbonisation targets. The core networks should be delivered by 2035, using the following levers:

- **Development expenditure** to enable front end engineering design studies to support infrastructure projects to get to the stage where they could apply for a development consent order.²²² The UK Infrastructure Bank can support the financing of hydrogen and carbon capture and storage projects, including through development finance.

- **Finalising business models** to manage the revenue risk projects will face, likely through a regulated asset base approach for carbon capture and storage and hydrogen pipelines and a revenue floor for hydrogen storage. Government should use competition in awarding these contracts for the build and operation of infrastructure to provide value for money.²²³
- **Establishing regulatory and governance systems, codes and standards** that avoid the risk of networks being developed in isolation and not being compatible as a joined up network.
- **Designating an independent system operator** for each network, tasked with efficiently managing its operation, and that could also take a role in planning the future shape of the network.

At each point in the process – ahead of awarding development expenditure or providing support through a business model – government should assure itself that the network being progressed has users at both ends.

The cost of building the Commission’s envisaged core networks for both hydrogen and carbon is uncertain.²²⁴ Reflecting uncertainty in development costs and the potential for reuse of existing natural gas pipelines,²²⁵ the Commission estimates the cost of building the core networks recommended will be in the range of £12-22 billion.

While core networks are being developed, government should ensure that planning for potential future stages of the networks is also in train, using an adaptive approach to manage the uncertainty and stranding risk while minimising the cost of inaction and delay. This will allow decisions to expand the network to be taken more quickly. Government should set out the adaptive process that will be followed when it sets out before the end of 2024 the vision for the core networks and the policies necessary to deliver them. Expansion beyond the core networks could involve facilitating imports and exports of hydrogen, extending the network to other industrial areas such as the Medway, providing carbon capture and storage to further dispersed sites, meeting additional demand from hydrogen fired generation or servicing new storage sites.

A core network for carbon pipelines and storage

The recommended core carbon pipeline and storage network offers a route to decarbonise parts of industry and support production of low carbon electricity generated using natural gas or biomass. The shape of the core network is driven by the following principles:

- Focus on delivery of a decarbonisation route for the largest emitters first, and target industries where carbon capture and storage is the most viable route for decarbonisation, for example cement and lime, carbon capture and storage enabled hydrogen production, the petrochemical industry and parts of the chemicals industry.
- Assume such industries are unlikely to move. The location of some industries is based on access to inputs which would be compromised if they had to move, for example cement plants are located close to sources of lime and silica. The impact on a local economy also makes moving industry infeasible.
- Account for the fact that some industries will reduce output as the economy decarbonises and therefore in the long term may no longer need access to carbon capture and storage, for example fuel production and oil refining.

- Provide a pipeline transport solution for large emitters as pipelines are likely to be the optimal transportation method to take large volumes of carbon from capture site to store.²²⁶
- Take carbon to stores that will be located offshore on the east and west coast.

Carbon capture and storage infrastructure is also needed to facilitate engineered greenhouse gas removals.²²⁷ These technologies will capture carbon dioxide directly from the atmosphere and permanently store it, creating negative emissions. These technologies are not yet built, so it is assumed they will be built in areas with access to the core network. This sector will be vital to reducing emissions in sectors that cannot fully mitigate their emissions. The Commission has previously recommended deploying a range of these technologies by 2030.

The core network does not provide a decarbonisation route for all existing energy from waste plants. These plants are highly dispersed and in areas where it may not be economic to provide a pipeline solution for transport of carbon. Non-pipeline transport, such as by road, rail, ship (or a combination), is likely to be a viable option for energy from waste plants and other industries and the core network should be built with ability to take carbon transported in these ways.

Based on the above principles the core network should connect Grangemouth and North East Scotland, Teesside, Humberside, Merseyside, the Peak District and Southampton (Figure 2.7).

The route developed between these core sites should maximise the opportunity to connect up:

- **Dispersed cement and lime plants** as these industries look likely to require carbon capture and storage to decarbonise and around half of the emissions from this industry come from sites located outside of the industrial hubs.²²⁸
- **Existing gas fired electricity generation**, as these sites have the potential to be retrofitted with carbon capture and storage or for the land to be used to build new.

Recommendation 15: Government should commit to the development of a carbon transmission pipeline and storage network that can transport and store at least 50MtCO₂e per year by 2035. The actions needed to deliver this are:

- **Set out a vision for an initial core network by the end of 2024, including clear identification of the key sites and routes. Based on current evidence, the Commission proposes the key sites for the core network should be Grangemouth and North East Scotland, Teesside, Humberside, Merseyside, the Peak District and Southampton.**
- **Support development expenditure costs for front end engineering design studies to bring projects in the core network to the point where they could apply for development consent.**
- **Establish a process beyond the existing allocation rounds (track one and two) for awarding regulatory asset base contracts for the build and operation of the core network. There should be the option of awarding business model contracts to pipeline and storage projects separately.**
- **Designate a system operator with a duty to efficiently manage the network and ensure network codes and governance arrangements are established in a manner fit for this purpose.**

- **Set out how decisions will be taken to add additional pipeline routes or stores to the core network, including timings and the decision making criteria for awarding development expenditure in the shorter term and business model contracts at a later date.**

A core network for hydrogen pipelines and storage

The recommended core hydrogen network connects the most likely initial sites of hydrogen demand, production and storage.

The shape of the core network is driven by the following principles:

- Focus on providing access to hydrogen for the most likely large users, which are situated in industrial hubs. For industry this includes chemicals, steel and users of high temperature heat where electrification looks challenging. It also includes sites with existing gas fired electricity generation which could be retrofitted or the land used to build new hydrogen fired generation.
- Connect these users to likely sites for both electrolytic and carbon capture and storage enabled hydrogen production.
- Ensure that networks pass through areas where it is most feasible to locate storage, particularly those sites that look most promising to develop first.

There are many industrial sites across the country that are not in industrial hubs. Some of these dispersed industries could use hydrogen but have not been prioritised in outlining an initial core network because demand is less certain. These sites could produce hydrogen locally or switch to electricity. Parts of the transport sector could also use hydrogen. Hydrogen can be tankered to refuelling stations or produced locally and therefore does not depend on the availability of a core network.

Based on the above principles the core network should connect Grangemouth and North East Scotland, Teesside, Humberside, Merseyside and South Wales (Figure 2.7). The argument for connecting South Wales largely depends on what role hydrogen plays in decarbonising the steel industry which makes up over 90 per cent of emissions in the area.²²⁹ If the steel industry does not require hydrogen then the case for a hydrogen pipeline to the area is weakened.

Recommendation 16: Government should commit to the development of a core hydrogen pipeline network that is operating no later than 2035. The actions needed to deliver this are:

- **Set out a vision for an initial core network by the end of 2024, including clear identification of the key sites and routes. Based on current evidence, the Commission proposes the key sites for the core network should be Grangemouth and North East Scotland, Teesside, Humberside, Merseyside and South Wales.**
- **Support development expenditure costs for front end engineering design studies to bring projects in the core network to the point where they could apply for development consent.**

- Expedite delivery of the planned business model for hydrogen pipeline networks which must include clarity on the process and timings for projects to receive business model support.
- Designate a system operator with a duty to efficiently manage the network and ensure network codes and governance arrangements are established in a manner fit for this purpose.
- Set out how decisions will be taken to add additional pipeline routes to the core network, including timings and the decision making criteria for awarding development expenditure in the shorter term and business models at a later date.

Figure 2.7: The core networks should connect Grangemouth and North East Scotland, Teesside, Humberside, Merseyside, South Wales and Southampton

Core pipeline networks for hydrogen and carbon



Source: Commission analysis

3. Growth across all regions



Major cities in England have significant potential to grow, but in some places public transport is insufficient to meet future demand

Urban transport networks are likely to need to accommodate significant numbers of extra passengers by 2055 to ensure employment growth is not constrained

Number of projected additional morning peak hour passenger journeys into the city centre in 2055; ranges based on Commission's central scenarios that assume city centres remain important locations for businesses, with significant levels of home and hybrid working



£22bn is needed to fund major public transport upgrades, with an initial focus on these four cities

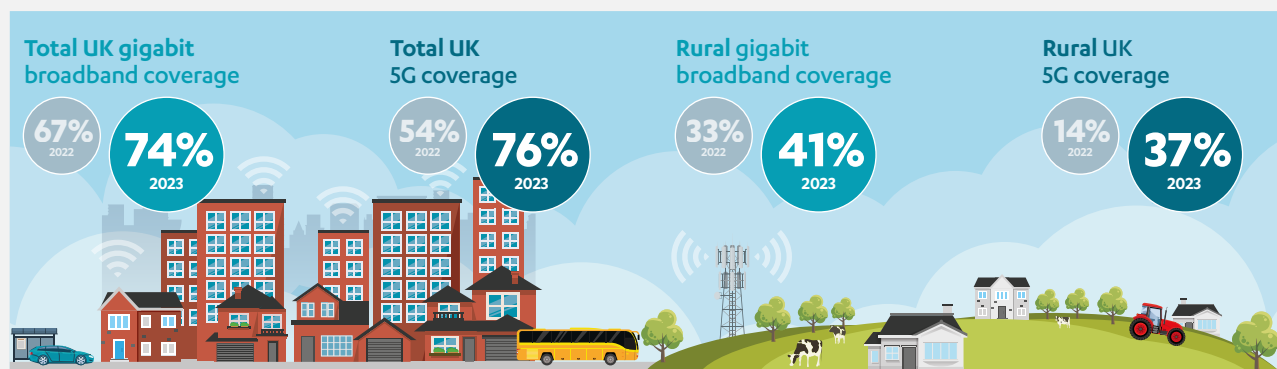
Future investment in longer distance road and rail should be prioritised to support growth across regions

The Commission recommends investing an average of **£15bn** per year on strategic transport between 2025 and 2040, rebalanced towards areas outside the South East



Digital connectivity is progressing at pace, but rural areas are lagging behind

Change in coverage between May 2022 and April/May 2023



Government must continue work to close this gap and ensure gigabit broadband is available nationwide by 2030.

Sources: Steer, Ofcom, Commission modelling

Infrastructure can best support more balanced regional growth by improving connectivity, which means better transport and digital networks. For transport networks, investment can facilitate sustainable trips within and between cities. For digital networks, government should secure nationwide coverage of gigabit broadband and 5G services.

England's largest cities are congested and their public transport networks underperform relative to comparable European cities. Government investment in mass transit is required in the largest regional cities to ensure they have the public transport capacity – seats and standing space on bus, trams and rail – they are likely to need in the future to support growth and quality of life. Government investment is also required to improve connectivity – the ability of people to get from one place to another – where this is an issue. The Commission's analysis suggests that the initial priorities for investment should be Birmingham, Bristol, Leeds and Manchester and their wider city regions, as growth in these places is likely to be constrained over the next 20 to 30 years unless they can increase capacity on their public transport networks. The government should make this financial support conditional on cities committing to introduce measures to reduce car journeys in city centres, and cities should provide a contribution to the funding of any large projects.

Transport budgets should be devolved to all local authorities responsible for strategic transport so that all places are able to maintain existing infrastructure – for example improving the condition of road surfaces – and invest for local growth. This will also help places develop locally led infrastructure strategies through which transport investment can be considered against long term goals and planned alongside housing and land use development. Locally led infrastructure strategies should also be used to ensure that transport infrastructure is accessible for all groups in society. London has a world class public transport system that supports its contribution to the national economy – government should agree a long term funding settlement to enhance and expand London's public transport network to unlock growth and housing opportunities, and support quality of life.

For the national road and rail networks, the government's first priority should be to maintain existing networks by investing adequately in maintenance and renewal, including ensuring resilience to climate change impacts. The government should then plan and invest in enhancements to the networks aligned to an integrated strategy for interurban transport, targeting underperforming sections of the network with enhancements that can facilitate trade in goods, and provide better connections between cities to facilitate trade in services. For the road network, a pipeline of projects with these aims in mind is required for the next 20 to 30 years.

Government had developed a long-term plan to improve rail performance between cities in the North and the Midlands. The High Speed 2 line between London and Manchester via Birmingham, alongside Northern Powerhouse Rail and other changes, would have improved north-south and east-west rail connectivity. This investment would also have freed up capacity on the existing rail network, enabling more local and regional services to run and providing significant increases to city centre accessibility. The Commission's analysis for government suggested that a package of these schemes would generate significant economic benefits for cities in the North and the Midlands from substantial capacity and connectivity improvements.

The second Assessment has been undertaken on the basis of the delivery of this long-term rail plan. On 4th October, government announced that High Speed 2 from Birmingham to Manchester will not go ahead and set out a new package of transport schemes. This decision leaves a major gap in the UK's rail strategy around which a number of cities have based their economic growth plans. While government has committed to re-allocate all the released funding to improve transport, including rail links, in the North and Midlands, it is not yet clear what the exact scope and delivery schedule is for the proposed new rail schemes. A new comprehensive, long term and fully costed plan that sets out how rail improvements will address the capacity and connectivity challenges facing city regions in the North and Midlands is needed.

Alongside better transport connectivity, government also needs to ensure that it supports high capacity digital connectivity across all areas of the country. The UK has seen strong progress on gigabit capable broadband in recent years. To continue this progress and meet its targets to deliver nationwide coverage by 2030, the government must continue to support network competition while delivering the £5 billion subsidy programme in the hardest to reach areas.

The government should also support a market led approach to 5G deployment by improving the consistency of planning approvals across the country and supporting access to radio spectrum for private networks. The government should prepare to act fast to support 5G deployment in areas where the market is unwilling to deliver should the need arise. Better digital connectivity will also be vital in supporting the needs of other infrastructure sectors. Between now and the end of 2026, the government should set out plans for how the telecommunication needs of the energy, water and transport sectors will be met, and ensure that the infrastructure needed is delivered by 2035 at the latest.

The challenge ahead

Transport and digital infrastructure allow people to access the things they need and want, and businesses to trade. These networks play an important role in supporting national and regional growth by supporting productivity and also improve quality of life for people by making it easier to access public services, retail and leisure activities and social networks.

Growth across all regions means supporting faster growth in low productivity regions and maintaining the economic performance of high productivity regions. Cities are the places with the most potential to grow – they have the highest employment density, largest concentrations of productive business sectors, and there is a strong relationship between the economic success of a city and its surrounding region. But large regional English cities are underperforming economically given their population size – this underperformance is one of the reasons that the UK's productivity is worse than comparable countries.²³⁰

Better transport infrastructure within cities can help support growth. It does this by enabling more trips within cities, which helps expand labour markets and attract business investment, and by facilitating the efficient movement of goods and services to support trade between cities and regions.

The policy challenge is how interventions can enable these economic benefits while decarbonising transport. The transport sector is the single largest source of carbon emissions in the UK. Transport decarbonisation, and the policies to support the take up of zero emission vehicles, are discussed in Chapter 2.

The Covid-19 pandemic highlighted the importance of investing in digital connectivity – faster, reliable, higher capacity fixed broadband connections enabled a sudden, widespread shift to homeworking in many workplaces. The sustained increase in home and hybrid working since the pandemic shows that gigabit capable broadband networks will only become more important as demand continues to grow.

The recent increase in home and hybrid working has not however negated the long term case for investing in improved transport networks into and between cities: over the next 20 to 30 years the largest cities are likely to need investment in more capacity if demand and growth are not to be constrained. This is the case across a range of scenarios for levels of home and hybrid working.

Alongside supporting increases in remote working, digital networks support economic growth and ensure that the UK remains competitive. Better digital infrastructure can improve workplace productivity and help to stimulate innovation through enabling new technologies and behaviours. 5G and other advanced digital technologies will enable UK businesses to adopt more efficient practices such as enhanced monitoring and automation, and will support new ways of working, including augmented and virtual reality.

Financial sustainability of public transport networks

Passenger numbers on public transport in cities declined following the Covid-19 pandemic and remain below pre-pandemic levels on average.²³¹ In Greater Manchester for example, overall passenger numbers on the bus network were estimated to be around 86 per cent of pre-Covid levels in June 2023, and commuter trips on the Metrolink tram network were around 88 per cent of pre-pandemic levels on average in January 2023, although on Tuesdays, Wednesdays and Thursdays this was typically reaching or exceeding 100 per cent of pre-pandemic peak commuter numbers.²³²

Lower overall patronage on public transport systems has meant that revenue remains below pre-pandemic levels in many places.²³³ This, combined with inflationary pressures on operating costs, has created financial challenges for urban public transport systems.²³⁴

There is a risk of a ‘doom loop’ for public transport, with insufficient funding requiring cuts to services, which then further reduces patronage and therefore revenues.²³⁵ Without further support or an increase in overall patronage levels of service will be difficult to maintain. This could lead to a permanent loss of services that would turn out to be necessary in the long run if employment and travel demand grow.²³⁶ Even if services are later reinstated, people may not return to using them, as changes to people’s travel patterns could be difficult to reverse.²³⁷

The government provided substantial financial support for public transport services following the Covid-19 pandemic – its immediate priority for supporting growth in cities should be to continue to ensure the financial sustainability of public transport services.²³⁸ The government continues to provide some support to maintain service levels, but funding support for light rail systems ended in 2022 and the government’s funding support for bus services up to 2025 appears insufficient to protect and maintain existing services – cuts to services are expected over the next two years and unless passenger numbers increase substantially over that period, continued funding will be necessary beyond 2025.²³⁹

The government should offer financial support to mayoral combined authorities to ensure the stability and reliability of their public transport networks over the next two years. During this two year period, the government should work with mayoral combined authorities to consider the long term sustainability and resilience of existing funding models for public transport systems, and the extent to which additional or new sources of funding will be necessary to secure this. This funding model should recognise the full value of public transport systems to people, the economy and the environment, and consider the revenue models used by urban transport systems in comparable countries.

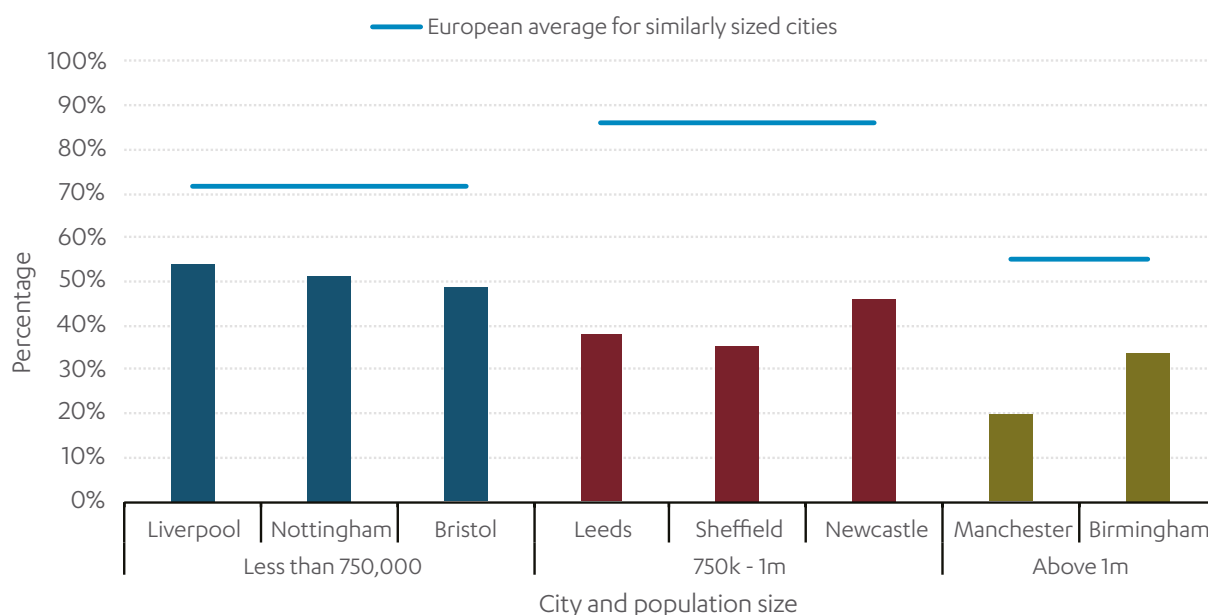
Better transport for cities

Cities are important for national growth, and also for driving growth in their wider regions. Cities enable highly skilled people and businesses to cluster together, in turn attracting more highly skilled people, businesses and services, and allowing expertise to be shared and workers and businesses to be more specialised. All these agglomeration effects can help make people and businesses more productive.²⁴⁰

However, large regional English cities are less productive than similarly sized European cities.²⁴¹ This is in part due to a lack of accessibility. Compared to equivalent European cities, fewer people in English cities can easily access city centres, see Figure 3.1, due to poorer transport networks and lower housing density.²⁴² This reduces the ‘effective size’ of the cities, meaning businesses do not have as wide access to labour markets as comparable cities, affecting productivity and growth potential. This underperformance of cities has a negative effect on national growth and contributes to regional disparities in England.²⁴³

Figure 3.1: Accessibility of city centres by public transport in large English cities is worse than for comparable European cities

Percentage of the city’s population that can access the city centre within 30 minutes by public transport



Source: Centre for Cities (2021), Measuring Up

Public transport investment to unlock growth

Better transport and increased housing density could help address this underperformance by increasing the ‘effective size’ of city centres. City centres in places like Birmingham, Leeds and Manchester have been rejuvenated in recent decades and have been successful in their own right, but they are not as accessible as they could be and this may have hampered growth in wider city regions.²⁴⁴ Improving public transport networks can help increase the ‘effective size’ of these cities and support growth. In comparison, it would not be possible for everyone to commute by car into English cities, given the levels of road congestion and impact on air quality.²⁴⁵

To improve public transport networks, some cities will need to invest in mass transit.²⁴⁶ Mass transit, using buses, trams and rail, or a combination of these, can increase capacity in the cities with the highest employment growth projections, connect parts of cities that were previously poorly served by public transport, and can carry substantially higher numbers of people than cars. Investment in mass transit should be aligned with policies on land use and housing within cities.

The government should prioritise public transport investment in places where poor public transport networks may be acting as a constraint on growth. Returns on this investment should be high, delivering productivity benefits as well as wider user benefits.²⁴⁷ Public transport investment should be targeted at the largest, most economically important cities with existing or projected needs based on capacity or connectivity. Government should consider whether there is also a case for investment in other cities.

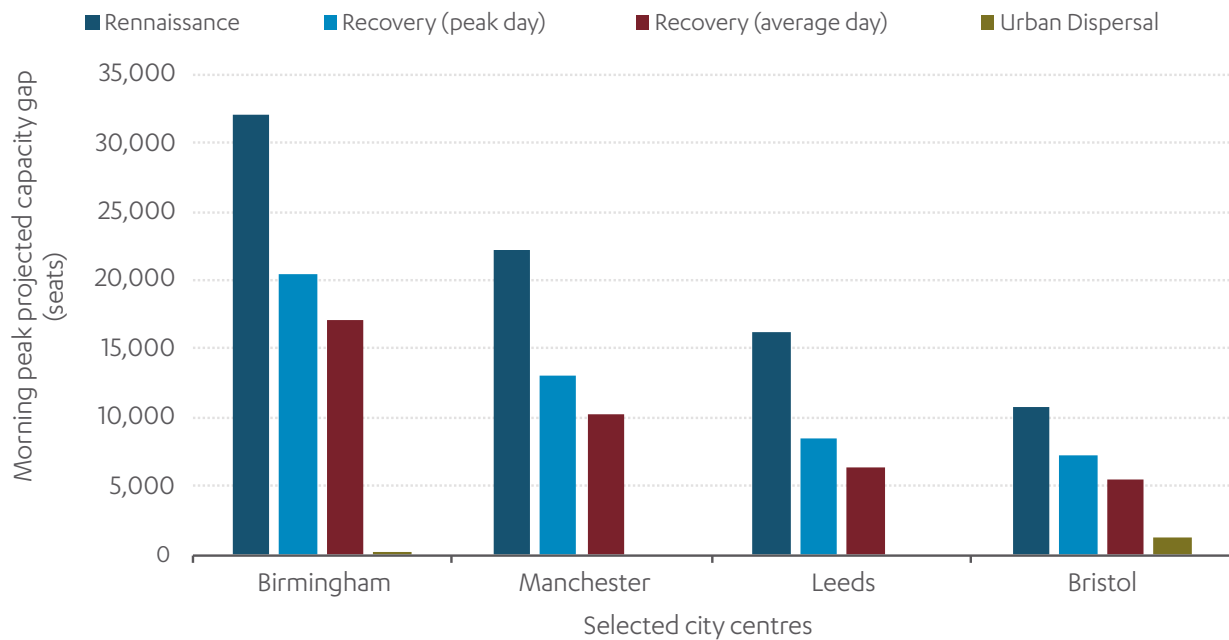
Addressing constraints to growth in four of the largest English cities

The Commission’s analysis has identified four cities likely to require substantial investment in public transport capacity to keep up with expected employment growth: Birmingham, Manchester, Leeds and Bristol.²⁴⁸ The expected shortfalls are shown in Figure 3.2. Investment will be necessary even if hybrid and home working remain above pre-pandemic levels. Box 3.1 sets out the Commission’s approach to scenarios.²⁴⁹

These four cities also have high projected population growth, and below average levels of public transport connectivity, as shown in Figure 3.3. These four cities are also among the largest in England in terms of economic size, and their performance has a large effect on growth in their surrounding regions.²⁵⁰ It is therefore vital to national and regional economic growth that productivity in these regions is maximised.

Figure 3.2: Birmingham, Manchester, Leeds and Bristol are likely to have substantial shortfalls in public transport capacity in the longer term given their expected employment growth, even if working from home remains established

2050 scenarios for extra capacity required in the morning peak hour²⁵¹

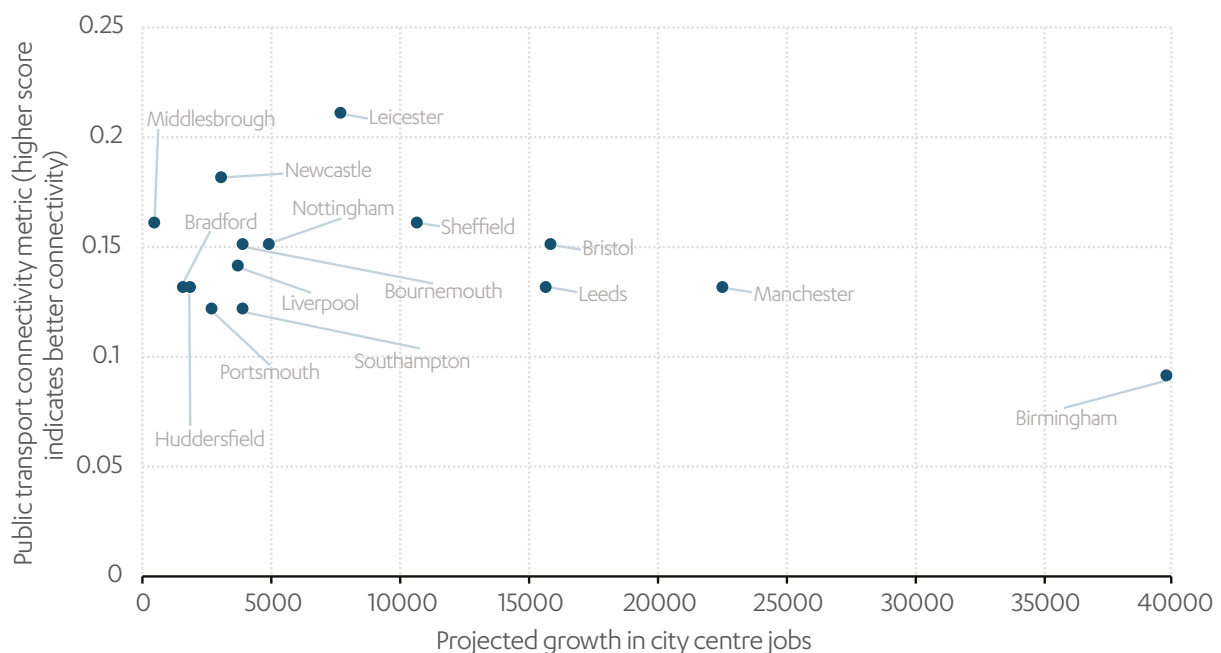


Source: Steer (2023), Urban Transport Capacity, Demand and Cost: Main Report

Note: The scenarios shown above have been selected to highlight the range of possible outcomes. Data for all scenarios are available in the full report by Steer.

Figure 3.3: Birmingham, Manchester, Leeds and Bristol have high levels of projected employment growth but relatively poor public transport connections

Public transport connectivity and projected city centre employment growth up to 2055 in the 15 largest regional English cities²⁵²



Source: Steer (2023), Urban Transport Capacity, Demand and Cost: Research Methodology; Prospective (2022), Transport Connectivity Methodology Report

Note: The data for employment growth projections was developed by Steer on behalf of the Commission, and the connectivity metrics are based on analysis undertaken by Prospective on behalf of the Commission. Projected employment growth is shown in absolute terms to illustrate the increase in capacity that it could require.

Government should commit £22 billion for major transport projects in cities. Two thirds of this should be for major transport projects in Birmingham, Manchester, Leeds, Bristol and their wider city regions. The scale of capacity increases that the Commission's analysis indicates are required in these cities are likely to justify investing in tram or rail based projects, although the exact type and mix of projects is a decision for cities to determine with government based on the costs and benefits.²⁵³ Given major scheme lead in times, project planning and business case development should proceed as soon as possible, as the Commission's analysis establishes the case to act.

Box 3.1: Developing different scenarios for future travel demand and patterns

Long term decisions on infrastructure should be robust to a wide range of possible future events, with plans not unduly biased towards one, or one set of, possible futures.²⁵⁴

The Commission has developed eight scenarios to reflect the uncertainty over future travel demand and patterns in cities. These are based on plausible combinations of variables that drive travel demand. The main variables are the role of agglomeration in cities — the economic benefits that are generated when people and businesses locate close to one another - and what this means for employment growth and where businesses choose to locate, and the long term uptake of home and hybrid working.

Of the eight scenarios, three are presented in Figure 3.2, corresponding to high, medium and low capacity requirements for the cities:

- **City centre renaissance:** This scenario assumes that city centres remain the optimal location for many businesses, given the continued role of agglomeration in generating growth, despite levels of home and hybrid working remaining at levels significantly above those before the Covid-19 pandemic. Although businesses based in city centres may need less office space due to changing working patterns, spare office capacity is taken up by businesses moving into the city centre from more peripheral locations.
- **City centre recovery:** These scenarios assume that city centres remain important locations for businesses, but the advantage of a central location is reduced as agglomeration effects decline, in part as a result of home and hybrid working remaining at levels significantly above those before the Covid-19 pandemic. Two variants of this scenario are presented in the chart above – average and peak day – which reflects uncertainty about how far workplace attendance will be concentrated on specific days of the week.
- **Urban dispersal:** This scenario assumes an increased uptake in home and hybrid working, to levels similar to those seen during the Covid-19 pandemic in 2021, and a large decline in the role of agglomeration in driving the growth of cities. This means city centre employment growth is lower, and jobs are dispersed from city centres.²⁵⁵

Addressing connectivity and capacity constraints in other cities

The remaining third of the £22 billion recommended investment in major transport projects should be allocated to other cities, where a strong case can be made on the basis of connectivity or capacity. Research suggests there may be a case for investment to expand the reach of public transport networks in some large cities: Liverpool and Sheffield (as well as Manchester and Leeds) have substantially smaller public transport networks than the average for comparably sized European cities.²⁵⁶ The Commission's analysis suggests there is also likely to be a case for investment in capacity in fast growing smaller cities such as Coventry and Norwich.

The government should carry out a more comprehensive analysis of capacity needs in smaller cities to see which ones should be prioritised. For smaller cities, it is likely that bus rapid transit, which operates like a tram or metro system but is substantially cheaper and more easily adapted, will be the most appropriate solution.²⁵⁷

Taking an adaptive approach to project development

The government should work with cities to help them develop pipelines of projects, which can be adapted to different futures. Government should make decisions in the late 2020s on which projects to commit funding support to for delivery in the early 2030s onwards. These decisions should reflect the latest analysis of how home and hybrid working, and other policy interventions, have changed demand and growth potential in cities. This should be earlier for places that are already developing plans, such as Leeds and West Yorkshire, which is the largest metropolitan area in Western Europe without a mass transit system.²⁵⁸

Projects to improve the performance of existing public transport assets, for instance through integrated ticketing and improvements to real time information should be taken forward under all scenarios to make best use of assets and encourage a growth in ridership. This approach – such as the Greater Manchester’s Bee Network – can also help provide the basis for a future expanded mass transit system.²⁵⁹

Recommendation 17: Government should commit long term funding of £22 billion for major transport projects in cities from 2028 to 2045. The initial focus for this funding should be on those cities that are likely to have the greatest need for increased capacity, justifying investment in rail or tram type projects – the Commission’s analysis indicates that these cities are Birmingham, Bristol, Leeds and Manchester. Some of this funding should also be made available to other cities where there is likely to be a need for increased capacity or connectivity. To reflect the uncertainty over future travel demand and cost, the total investment package should be reappraised before final decisions are made on which projects to take forward.

Further encouragement to travel by public transport and active travel

Mass transit investment alone is unlikely to be sufficient to encourage greater use of public transport. In most cities with existing mass transit systems, the car is still the main mode of travel.²⁶⁰ Further measures will be required in the largest cities to reduce car journeys, particularly at peak times.

To help consider the suitability and impact that measures such as congestion charging, workplace parking levies and physical measures to limit vehicle movements could have in English cities, the Commission has analysed ten case study cities from around the world.²⁶¹ For example, Nottingham introduced a successful workplace parking levy in 2012 (see Box 3.2). Leeds City Council has carried out a number of projects in the city centre to reduce traffic and improve the public realm, such as bus priority corridors, bus only gateways and pedestrianisation.²⁶² These examples suggests that, under the right conditions, these measures can play an important role in addressing congestion and improving capacity. This is because a

reduction in road traffic demand creates space for additional, more reliable public transport, such as through priority bus lanes. Measures like these are more space efficient than cars, and the road space that is freed up will provide the additional capacity that will allow for more journeys into the city centre.

An important principle for any charging scheme is that the revenue raised is ringfenced and spent on public transport, cycle lanes and walking infrastructure improvements. Research by the Commission into public attitudes towards congestion charging showed that support for measures increased when people understood that the revenue raised would be spent on improvements to local transport.²⁶³

But measures that reduce car journeys will only support growth if they are enacted alongside measures to increase public transport capacity and connectivity. Any interventions that reduce trips by driving where there is no viable public transport or digital alternative will hinder, not support, growth and have negative social impacts.²⁶⁴ This means that measures are most likely to be successful in larger cities where improvements to increase the frequency and reliability of public transport networks are planned.

It is also possible to reduce demand for car travel within city centres by limiting the places or routes into which cars are able to go.

The exact form of any measures should be a decision made by individual cities, which are best placed to understand the local context and respond with appropriate design (for example, the hours of operation) and sequencing of interventions. This includes considering who will be most affected by any charging scheme. The households that are likely to be most affected by any charging scheme are those from higher income groups, as they travel more frequently. However, people on lower incomes who rely on the car for most journeys may still be negatively impacted, and certain ethnic groups are disproportionately represented in lower income groups.²⁶⁵ Cities will have to ensure that any charging scheme does not disproportionately impact people on lower incomes and consider mitigating actions such as targeted exemptions or public transport subsidies.

Recommendation 18: To encourage modal shift and enable an increase in trips in congested cities, government should make the long term funding for major projects outlined in recommendation 17 conditional on recipient cities committing to introduce a demand management scheme, in a way that is designed to work best in the local context. The exact form and sequencing of the demand management scheme should be a decision for the individual city, and the revenue raised should be retained by the local area for investment in public transport and active travel.

Raising more revenue locally to help fund mass transit investment

Central government grants will need to be the primary source of capital funding for major transport projects in cities. The cost of mass transit systems means that they will not be able to be funded locally, and grants provide a mechanism to better spread public funding beyond London and the South East.²⁶⁶

Cities should nevertheless be expected to contribute towards the costs, given that it is people who live and work locally and local businesses who will primarily benefit from these investments. But the ability of cities to raise revenue is limited, particularly when compared to comparable countries.²⁶⁷ Other countries allow local government to levy substantial taxes on incomes and consumption. New York City has at least 22 local taxes, compared to just two for cities in England: council tax and business rates.²⁶⁸ And local authorities have little control over the base and rate of council tax.²⁶⁹

There are two main ways local authorities could raise additional revenue locally to support transport: fiscal devolution and transport user charging.

The Commission does not have a view on the best form of fiscal devolution – any transition would need to be approached gradually and carefully given the differences that local authorities would have in their ability to raise funds locally. However, the case for some form of fiscal devolution is a strong one. Increased local revenue raising would grant local leaders the autonomy to raise funds to finance local regeneration, help create stronger incentives to focus on economic growth, and further increase their accountability to voters.²⁷⁰ Some initial ways to increase fiscal devolution include mechanisms such as business rate relief, business rate retention or land value capture. Many combined authorities already have the power to do some of these.²⁷¹

As set out earlier, transport user charging could be via a congestion charge or workplace parking levy, to create a possible new source of revenue for local authorities. The Commission's analysis suggests a cordon based congestion charge or workplace parking levy could raise in the region of £10 and £50 million a year in the largest English cities. To put this into context, the UK Infrastructure Bank cited as an example that a revenue stream of £10 million a year could be expected to allow a local authority to borrow around £150 million under current market conditions (assuming a 30 year repayment term).²⁷²

There are various sources of financing available to support infrastructure projects. Local authorities can borrow against future revenues from the Public Works Loans Board.²⁷³ The UK Infrastructure Bank has £4 billion available to lend.²⁷⁴ Private finance may also be an option – appetite appears to exist amongst lenders, but there are some possible difficulties that stakeholders have raised with the Commission, for example who bears the demand risk, and it may be difficult for cities to raise financing at competitive interest rates.²⁷⁵

Box 3.2: Nottingham tram extension – an illustrative example

Nottingham offers a good example of taking a holistic approach to public transport investment, demand management and new revenue streams. Nottingham introduced its workplace parking levy in 2012 with the aim of reducing congestion in the city.²⁷⁶ All employers with more than ten employees are obliged to pay a flat fee for each parking space that they provide for employees. By 2022, the Nottingham levy was estimated to have reduced congestion growth by 47 per cent and CO₂ emissions by 5,780 tonnes.²⁷⁷

The revenue raised from the levy was earmarked for helping to fund an extension to the city's tram network. The extension, which opened in 2015, cost £570 million, with 35 per cent of the funding provided locally, provided largely by borrowing against the future revenue raised from the levy, which is around £10 million a year.²⁷⁸

Central government needs to work with local authorities to assess their ability to raise revenue locally to contribute towards major transport projects, whether through existing or new revenue streams. The circumstances in each place, and of each project, will be different, so it is difficult to be too prescriptive about the level of contribution and possible new revenue sources.

Under the first round of the city region sustainable transport settlements, the Department for Transport said that city regions would be expected to raise at least 15-20 per cent local contributions towards capital enhancements, and this is expected to be achievable.²⁷⁹ In the first Assessment the Commission recommended that cities benefiting from major transport projects should provide at least 25 per cent of the funding.²⁸⁰ The government should take a flexible approach depending on local circumstances, including on the type of scheme and ensuring integration with wider local economic strategies. Higher contributions should be scored positively in business cases.

Recommendation 19: The cities that directly benefit from the major transport projects outlined in recommendation 17 should make a significant contribution to the capital costs. Government should expect a local contribution of at least 15 to 25 per cent towards the total cost of the investment – although there are scenarios where a higher contribution may be expected, particularly for less expensive investments. Government and the UK Infrastructure Bank should work with cities to investigate and facilitate financing mechanisms and funding sources that could include a combination of business rates retention, third party contributions, forms of land value capture, and new income streams, to support the delivery of local public transport infrastructure.

Devolved budgets for all areas to maintain assets and invest for growth

All local authorities responsible for strategic transport need to have sufficient funding to maintain existing assets and invest in smaller network enhancements, such as zero emission buses. This includes ensuring there is adequate funding for cities to maintain and renew existing mass transit systems, such as those in Liverpool, Newcastle and Sheffield.

It is essential that central government gives all local authorities that are responsible for strategic transport planning devolved budgets that allow them to plan for the long term. Local authorities are better placed than central government to determine what their priorities are for transport investment, as they better understand local issues and opportunities. This will also help places develop locally led infrastructure and growth strategies through which transport investment can be considered alongside housing and land use development.

But the current structure and complexity of local government funding does not allow for this. There are multiple funding streams that can only be spent on centrally determined priorities, and local authorities often have to bid against each other to access them, preventing long term planning and diverting scarce resources towards putting bids together.²⁸¹

This situation has improved recently with the introduction of the city region sustainable transport settlements. The first round covers 2022-23 to 2026-27 and a second round was announced in 2023 to cover the five year period from 2027-28. The settlements provide mayoral combined authorities with five year funding to cover maintenance, renewals and smaller enhancement projects. The scheme (in the first round) has not resolved all the issues with local transport funding:

- central government retains too much control over how budgets within the settlements are spent
- it still involves bidding for funding, which stakeholders have told the Commission is costly and time consuming
- the settlements have not been put on a permanent footing.

However, the settlements are a good first step towards longer term and simplified funding arrangements. The next step is to roll out similar five year settlements beyond mayoral combined authorities to other authorities which are responsible for strategic transport. This should happen faster than the government's ambition of providing devolution deals and simplified long term funding to all areas that want them by 2030.²⁸²

The Commission also welcomes the announcement of the recent single, multi year financial settlements for Greater Manchester and the West Midlands.²⁸³ These deals, due to commence at the next Spending Review, will provide much needed flexibility over the use of funding, making it easier for places to plan integrated long term strategies that can address local transport priorities in a way that is aligned to other policy goals such as housing, skills and economic development. Similar settlements (which will incorporate the funding from the city region sustainable transport settlement funding) should also be agreed with the other combined authorities at the next Spending Review.

The Commission recommends that the government supports £8 billion of annual investment in local transport, which should consist of a combination of devolved budgets and locally raised revenue. This represents a 20 per cent increase on current spending levels, spread across all different area types. The government should also provide greater certainty for places that these five year settlements will be renewed, enabling longer term planning and capacity building.

Recommendation 20: Government needs to move faster in devolving powers and funding for local transport to local authorities. By the next Spending Review, government should have agreed single multi year financial settlements for existing mayoral combined authorities to invest in local priorities, and then continue to roll these out to new mayoral combined authorities. All county councils and unitary authorities that remain responsible for strategic transport planning should be provided with devolved five year transport budgets by the end of 2025, sufficient to cover maintenance, renewals and small to medium enhancements.

Government should ensure that £8 billion a year is available for devolved transport budgets for local authorities outside London, consisting of a combination of central government grants and locally raised funds.

A long term funding settlement is required for London

Investment in regional cities by central government should be in addition to investment in London. London is important for national growth – it is projected to grow faster than any other English city, and the taxes paid in London help fund infrastructure and other services in other parts of the UK. In 2020, London contributed £4,030 per person to the rest of the UK.²⁸⁴

Transport for London's current capital investment plans take a prudent approach to uncertainty, reflecting changes to travel demand following the Covid-19 pandemic. The focus is on protecting core assets and service renewals to maintain the performance and reliability of the public transport network in the 2020s, with spending on enhancements and extensions to increase the connectivity of the network in the 2030s (for example, the Bakerloo line extension to South East London).²⁸⁵

Passenger numbers on public transport in London have not yet recovered to pre-pandemic levels – monthly journeys on London buses and the London Underground in 2023 have been on average around 84 and 82 per cent of 2019 levels respectively.²⁸⁶ Given the corresponding reduction in revenue, Transport for London has received a number of emergency, short term funding deals from government which have provided revenue support and capital funding. The latest deal runs to March 2024.²⁸⁷ A new longer term model for capital investment should be agreed at this point, as is the case for other major cities, to enable the continued enhancement and expansion of London's public transport network, which will unlock growth opportunities and additional housing.

Transport for London has demonstrated previously that major transport enhancements are deliverable with the right support. It has developed diversified funding and financing models in partnership with central government to support projects like the Northern Line extension, the Elizabeth Line and the Barking Riverside extension.²⁸⁸ A longer term funding settlement is needed to enable Transport for London to plan with more certainty for both important renewal activities, such as rolling stock and signalling infrastructure, as well as further enhancements that will take years to develop and deliver – at present it is estimated that there is a funding gap of £20 billion up to 2042.²⁸⁹ The long term settlement should include grant support from central government beyond the current business rates arrangements, reflecting the contribution of London to the national economy, as locally raised revenue streams generated from the

direct beneficiaries of the transport schemes. The alternative to grant support may be to allow London to retain a greater proportion of the taxes and revenues it generates through some form of fiscal devolution.

Recommendation 21: Government should replace short term funding deals for Transport for London with five year funding settlements, sufficient to enable both the renewal and enhancement of London transport. Government should work with the Mayor of London to establish the priorities for public transport enhancements over the next 10-20 years and reach agreement on the appropriate combination of grant support, retained business rates and local mechanisms that can be used to finance and fund them.

National road and rail networks

The national road and rail network is essential for connecting places — the road network reaches every settlement in England. The UK's economy is structured around the existing network — economic growth is dependent on the road and rail networks providing good transport links between major cities. These connections support trade in services and goods, which includes freight and business travel.

Performance of the national road and rail networks

Long distance passenger trips are predominantly taken by car. Eighty-two per cent of trips over ten miles are either as a driver or passenger of a car or van, while rail trips accounted for only ten per cent of passenger trips over ten miles in 2019.²⁹⁰ Freight is a significant user of both road and rail: freight vehicles make up 32 per cent of vehicle miles on the strategic road network, 20 per cent of vehicles miles on the major road network, and 20 per cent of all vehicle kilometres on the rail network.²⁹¹

Traffic on the national networks was substantially reduced as a result of the Covid-19 pandemic. Road traffic volumes have recovered to 97 per cent of pre-pandemic levels by the year ending June 2023,²⁹² but recovery on rail has been slower and had only recovered to around three quarters of 2019-20 passenger levels by 2022-23 (the recovery on rail may have been impacted by industrial action).²⁹³

Maintenance and renewal of these networks is likely to be more expensive in the future because of the impact of climate change, assets reaching lifespan limits and increased demand leading to greater wear (although technological change may have benefits for maintenance needs and approaches).²⁹⁴ Historical levels of spend are unlikely to be sufficient to provide outcomes similar to today. Given the UK has a mature network, prioritising the performance of the existing network matters most for productivity and competitiveness.²⁹⁵

Maintenance of the road and rail networks, and renewals on the rail network, should therefore be prioritised. As set out in Chapter 4, the government should set realistic standards and determine the level of maintenance and renewal needed to meet these. As well as the national road and rail networks, this should also apply to local roads — where there has been a historic backlog of maintenance spending — and to local public transport.²⁹⁶

Connectivity enhancements on the national road networks

Alongside maintaining the existing network, the government should also take forward a programme of connectivity enhancements for national road networks. Better connectivity will help improve trade efficiency, making it easier for businesses to move freight and trade goods and services.²⁹⁷

The government should prioritise investment in the connectivity enhancements that will best help the national networks to facilitate trade between places. It is not clear that this happens at present — the selection of road and rail projects which the government has taken forward has not always been undertaken on a sufficiently strategic or transparent basis and does not appear to effectively balance national and regional productivity goals. For example, the allocation of funding in the second Road Investment Strategy was not consistent with helping underperforming regions — while connectivity benefits may not always fall within the region where spending occurs, only 22 per cent of funding allocated was in the North and the Midlands.²⁹⁸

At present, National Highways produces route strategies, which are the basis for the first stage of the process to produce the Road Investment Strategy.²⁹⁹ This exercise provides good quality information on the range of options the government has, but it has not always been clear how final decisions on prioritisation of enhancements follow from this analysis.

Prioritisation should be undertaken on the basis of a systematic analysis of how and where connectivity could be most improved, starting with a clear understanding of which routes are most important for trading relationships between places, particularly the largest cities and towns and key freight hubs. It should then identify which sections of these important routes underperform in terms of journey times, or where there may be missing links in the existing network. This exercise should include the Strategic Road Network and the Major Road Network, and it should be complementary to wider growth strategies, given transport is necessary but not sufficient for improving productivity.

Alongside this systematic analysis, the government should also engage with regional authorities — sub national transport bodies, mayoral combined authorities and pan regional partnerships — to understand their priorities, and identify where there may be opportunities for transport to support regional and local growth strategies that are not captured by analysis of the current network. Examples may include where new industrial development capacity requires new connections to be opened up, or where connecting new low carbon energy sources and users could support decarbonisation of the regional economy.³⁰⁰

Prioritising investment in the national road network

Progress on the third Road Investment Strategy is already advanced, with a draft strategy expected later this year.³⁰¹ This strategy should go ahead on the basis of projects that the government already has in development but should also set the longer term vision for the national road network, using the Commission's analysis.

The Commission has developed a portfolio of road enhancement options using the approach outlined above, which identifies the worst performing routes on the network with substantial demand potential between key cities and towns. The portfolio has been developed within

the proposed budget for road investment to cover the next 20 to 30 years. It is based on the demand for travel between cities and towns and also considers freight demand and usage – the high demand routes are largely the same for people and freight. And it is assumed that the most significant projects in the second Road Investment Strategy have been completed.

Measurement of the benefits that these enhancements would bring to different places is based on the Commission's connectivity metric (which is explained in Box 3.3). The connectivity metric demonstrates the benefit of enhancements in terms of transport performance; quantifying the effect of this on economic outcomes is difficult to do, but investment in improved road connectivity can generally be expected to lead to an increase in GDP.³⁰²

Box 3.3: The Commission's connectivity metric

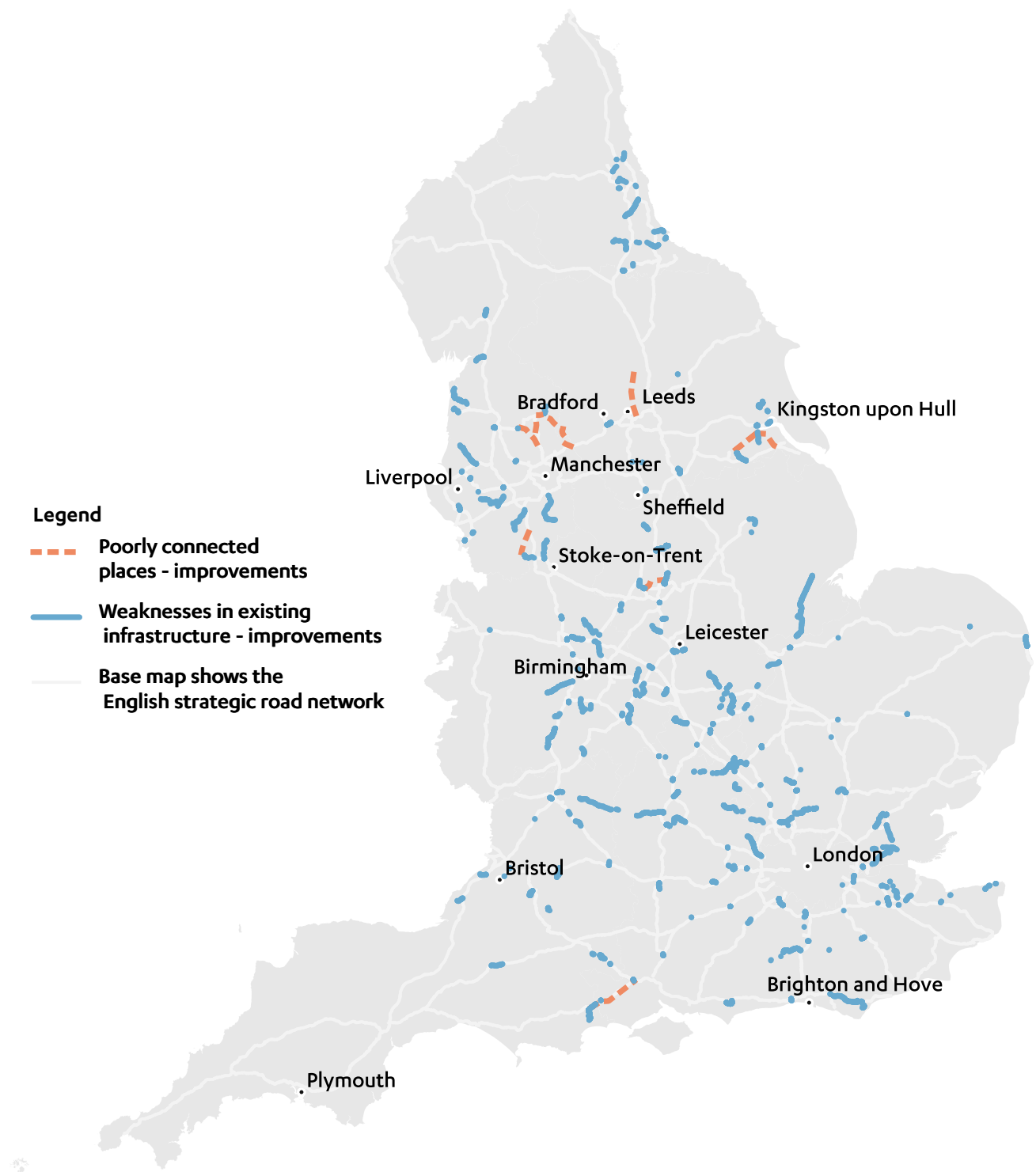
The Commission's connectivity metric gives each place in Great Britain a score to denote how well connected it is to other places. The score is calculated by taking the average travel time between a given place and other places in Great Britain, and weighting them by population and distance, which are useful indicators of likely demand for travel between places. For example, the journey time between Manchester and Liverpool would carry more weight in calculating Manchester's connectivity score than the journey time between Manchester and Hastings would do, as more people are likely to want to travel between Manchester and Liverpool than Manchester and Hastings.³⁰³

This approach works better than comparing current traffic flows between places as a particularly slow or unreliable route between two places may reduce the volume of traffic between them.

The underperforming routes that should be targeted for investment are shown on the map in Figure 3.4.

Figure 3.4: The Commission's suggested portfolio of priorities for investment on the national road network

Map showing location of suggested long term priorities for investment on the national road network over the next 20 to 30 years



Source: Steer (2023), [Interurban Transport Connectivity Assessment](#)

This portfolio would help improve connectivity in underperforming regions. Investment is weighted more heavily towards these regions than was the case in the second Road Investment Strategy. At the same time this portfolio includes making improvements to the road network in regions with high productivity. This is demonstrated by the expected connectivity benefits shown in Figure 3.5.

Figure 3.5: All regions of England benefit from an approach to road investment that targets the worst performing routes

Improvements to connectivity for each region of England, versus its baseline connectivity score, if the Commission's portfolio of road investment is followed

Region	Baseline connectivity score	Potential increase in connectivity score
London	0.52	9.0%
South East	0.85	8.3%
South West	1.18	12.1%
East of England	0.72	5.2%
East Midlands	0.99	6.2%
West Midlands	1.13	6.3%
Yorkshire and The Humber	1.11	6.9%
North West	1.04	4.0%
North East	1.17	9.9%

Source: Steer (2023), Interurban Transport Connectivity Assessment. The baseline connectivity score is based on today's road network. The score for each region is based on the average connectivity score for each built up area within that region. For each built up area, the travel time between it and all other built up areas in the country is calculated, with travel time between places weighted by the demand in each place (which means the travel time between bigger, closer places counts for more than the travel time to smaller, further away places). The result is expressed as a ratio of the connectivity to all other places by observed speed versus straight line crow flies speed (50 kilometres per hour). This means that a figure less than one shows that overall demand weighted travel speed is less than 50 kilometres per hour to all other places; a score greater than one means demand weighted travel is greater than 50 kilometres per hour. In London the figure is significantly affected by central congestion. Connectivity improvements can occur beyond the region where the investment occurs. London's baseline connectivity is low as the score is based on travel time to the centre of London.

The Commission's portfolio represents a vision for the network, not a detailed delivery plan – further work would be needed as part of future iterations of the Road Investment Strategy to develop specific project options on each of the areas highlighted, and to make decisions about viability and prioritisation. There are also options to develop the Commission's approach further, depending on the government's wider economic and regional strategy.

Road investment will need to be compatible with plans to decarbonise transport. As discussed in Chapter 2, transport is the sector with the largest carbon emissions in the UK and longer distance travel makes a large contribution. Ninety-one per cent of emissions from domestic transport come from road vehicles, and car journeys of over ten miles account for 55 per cent of personal travel mileage by road.³⁰⁴ Emissions from road use will have to be abated in full by 2050, and very substantially by the mid 2030s, primarily by the move to zero emission vehicles, in line with the recommendations set out in Chapter 2. However, while credible decarbonisation plans are essential, the additional emissions from the plans proposed above will not themselves substantially alter the scale of the challenge. Traffic demand is projected to increase by ten to 28 per cent by 2035,³⁰⁵ primarily due to economic and population growth, while a road enhancement programme over that period would be expected to increase demand by around 0.6 to 1.3 per cent.³⁰⁶

The road network, and enhancements to it, also affect other environmental issues including biodiversity and air quality. These impacts are discussed in Chapter 4.

Recommendation 22: Government's first priority for roads should be to maintain the existing network by investing adequately in maintenance and renewal, including to ensure proportionate resilience to climate change impacts. Government should enhance the road network on a strategic basis, with improvements targeted at underperforming sections of the network, aligning schemes with complementary policies for economic growth and giving initial priority to interventions in regions with underperforming productivity.

By the end of 2026 and ahead of commencing work on Road Investment Strategy 4 (2030 to 2035), government should use the improvement options outlined in the Commission's analysis, alongside projects identified in partnership with sub national transport bodies, mayoral combined authorities and pan regional partnerships that unlock regional economic opportunities, to develop a pipeline of future interurban road projects over a thirty year horizon.

Maintaining levels of investment in the national rail network

The rail network supports economic growth through its role in transporting large numbers of people into congested city centres and providing high speed rail links between cities, where rail is faster or more convenient than travelling by car.

Investment in rail can also contribute to reducing regional disparities — rail journeys between major cities in the North and the Midlands tend to be slower than those in London and the South East, and those in regions with higher levels of productivity in comparable European countries.³⁰⁷ Train services in the North and the Midlands can also be unreliable — CrossCountry, Northern Trains, East Midlands Railway, Hull Trains and TransPennine Express consistently perform worse than the national average for trains arriving on time.³⁰⁸

Government had developed a long term plan to improve rail performance between cities in the North and the Midlands.³⁰⁹ The High Speed 2 line between London and Manchester via Birmingham, alongside Northern Powerhouse Rail and other changes, would have significantly improved north-south and east-west rail connectivity. This investment would also have freed up capacity on the existing rail network, enabling more local and regional services to run and providing significant increases to city centre accessibility. By creating a long term pipeline, the plan was designed to give confidence to the UK supply chain to invest in skills and capability.

The Commission's analysis for government suggested that a package of these schemes would generate significant economic benefits for cities in the North and the Midlands from substantial capacity and connectivity improvements. As an illustration, the productivity (agglomeration) and amenity benefits for this investment package (excluding the effects of High Speed 2 Phase 1 and Phase 2a) were estimated to be between £41 billion and £77 billion, with additional benefits derived from faster and more frequent longer distance journeys. The economic gains are potentially higher still if city centres experience transformational changes in productivity following the investments alongside complementary interventions.³¹⁰ Good rail connections into and between cities tend to be present in comparable groups of cities in other countries.³¹¹ And none of England's economic comparators, with similar geography, have poor rail accessibility between cities.³¹²

The second Assessment has been undertaken on the basis of the delivery of this long term rail plan. On 4th October, government announced that the later phases of High Speed 2 from Birmingham to Manchester (Phases 2a and 2b) and from Birmingham to the East Midlands (HS2 East) will not go ahead and set out a new package of transport schemes.³¹³

This decision leaves a major gap in the UK's rail strategy around which a number of cities have based their economic growth plans. While government has committed to reallocate the funding from cancelling the later phases of High Speed 2 to improve transport, including rail links, in the North and Midlands, it is not yet clear what the exact scope and delivery schedule is for the proposed new rail schemes. A new comprehensive and long term strategy that sets out how rail improvements will address the capacity and connectivity challenges facing city regions in the North and Midlands is needed. Government should undertake an urgent review of rail priorities involving local leaders and bring forward a rigorously costed portfolio of schemes with clear delivery timescales. The Commission could support government in undertaking this work. Alongside this, government should also take a hard look at the governance and delivery arrangements for future rail projects to learn lessons and ensure that project design and management, supply chain contracting and oversight are set up to exert a tight grip on costs and ensure value for money.

The government has also committed to the East West rail link for Cambridge, Milton Keynes and Oxford. This is a transport scheme which has been designed to support high productivity areas by removing a constraint to growth. The rail link is expected to be used for commuting, leading to denser housing development around the stations on the route. The number of stations will be limited to safeguard commuting times, with the focus on larger scale development around a smaller number of transport hubs and interchanges.³¹⁴ It is important that long term funding is made available for the full route to enable construction of the remaining parts of the line to start in mid 2020s.

In addition to plans to upgrade existing main lines in the North and Midlands,³¹⁵ government should also continue to make provisions for rail improvements on other network priorities over this period through a long term pipeline with five year delivery programmes, including schemes that should target issues such as station capacity, signalling and resolving bottlenecks.

Recommendation 23: Government should prioritise maintenance and renewal of the existing rail network, ensuring proportionate resilience to climate change impacts. Government should develop a new comprehensive and long term plan for rail enhancements to address the capacity and connectivity challenges in the North and Midlands, alongside completion of East West Rail and a portfolio of targeted network enhancements across the country.

Developing a national integrated transport strategy

In order to align the processes of road and rail capital investment, the government should set a long term investment pipeline across road and rail around an indicative total budget envelope and with clear common strategic objectives. This should incorporate a strategic vision for the main transport corridors which includes both road and rail, ensuring that they are considered together and not separately.

The long term pipeline would have key and secondary priorities identified within it and a framework for how to manage cost and scope change. A combined pipeline would allow the government to consider a range of transport solutions and consider their cumulative impact. This opens up the opportunity to examine issues together in a strategic way, which should include how transport strategies can best support wider regional and local economic goals.

The long term pipeline should also give the government options to adapt and respond to uncertainty and new opportunities, for example the effect that the widespread deployment of connected and autonomous vehicles could have on the national road network. The Commission's analysis shows that if a high uptake of connected and autonomous vehicles enables safe maximum speeds to increase to 80 miles per hour on uncongested long distance main roads, they could provide connectivity improvements comparable in scale to tens of billions of pounds worth of road investment. Given these possibly significant benefits, along with the potential for road travel to be made more accessible to those who currently do not drive themselves, the government should establish what will be needed to realise the benefits of connected and autonomous vehicles, as well as to mitigate any negative consequences such as an increase in urban congestion. This may include infrastructure improvements to support cars driving in different ways, adequate digital connectivity, and further regulation on use of these vehicles.

The Commission is happy to work with the Department for Transport on the outstanding areas required to develop an integrated transport strategy, such as the interaction between strategic transport and local transport systems.

Recommendation 24: By the end of 2026, government should develop an integrated strategy for interurban transport to frame the development of Control Period 8 for rail (2029-34) and Road Investment Strategy 4 (2030-35). This should incorporate a long term vision for network performance and resilience, a pipeline of strategic improvements to road and rail over the next 30 years, as outlined in recommendations 22 and 23, and a plan for decarbonisation, as outlined in recommendation 13. It should also set out government’s approach to harnessing the benefits of new technology and achieving environmental net gain.

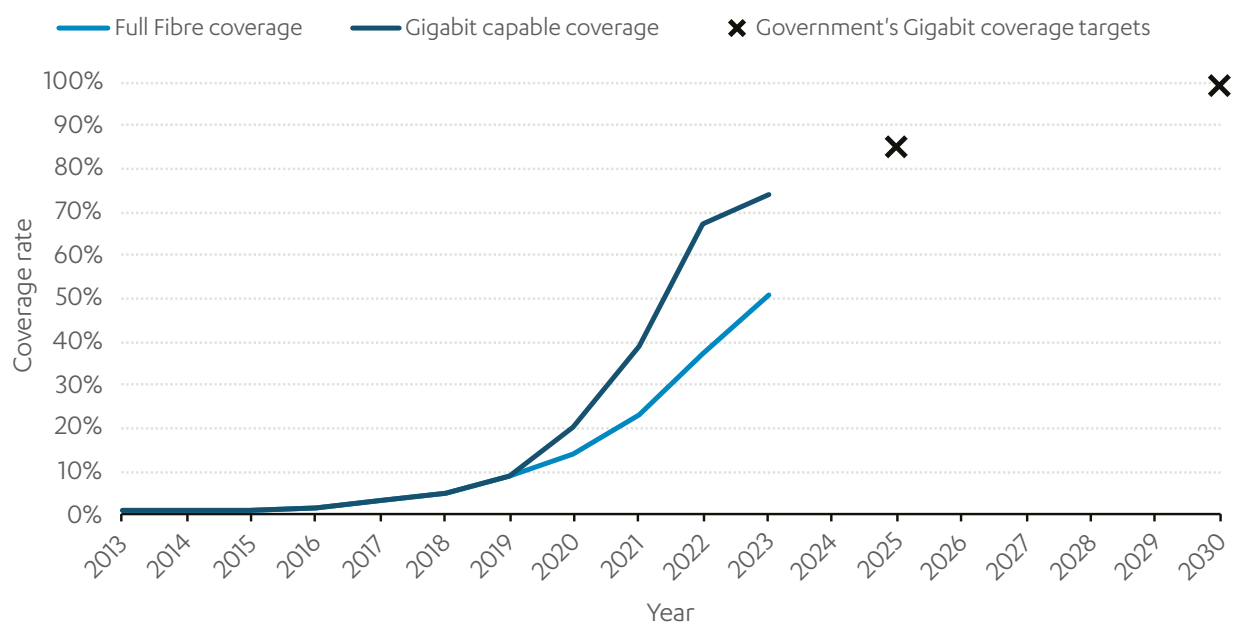
Digital rollout in the UK

Fixed broadband networks

Good quality broadband networks are crucial for economic growth. Better broadband connectivity can lower costs for firms, enable productivity enhancing technological change and widen access to labour markets across the country. For instance, a study undertaken for Ofcom found that between 2002 and 2016 there was a cumulative 6.7 per cent increase in UK GDP due to increased broadband adoption and speed improvements.³¹⁶

Figure 3.6: The government is on track to deliver its gigabit capable targets

Historic UK coverage 2013 – 2023 and government targets up to 2030



Source: Ofcom Connected Nations: summer update (2023); thinkbroadband, UK gigabit capable and full fibre coverage

Note: Figures from 2017 to 2023 are from Ofcom Connected Nations reports. Figures for 2010 to 2016 are from thinkbroadband. Figures are for May of each year.

The UK has seen strong progress on gigabit capable connectivity in recent years from around five per cent in 2018,³¹⁷ when government published its long term strategy for broadband,³¹⁸ to 74 per cent today.³¹⁹ Rural coverage (41 per cent) is however lagging behind urban areas (79 per cent).³²⁰ Since the last Assessment, the government has committed £5 billion to fund rollout of gigabit capable broadband to the hardest to reach premises across the UK and has undertaken, alongside Ofcom, significant policy and regulatory reform to support rapid deployment of gigabit capable networks.³²¹

Industry has made a series of positive commitments on gigabit capable rollout. Openreach has committed to spend £15 billion to deliver full fibre to 25 million premises across the UK by the end of 2026; as of March 2023 it has reached at least ten million premises.³²² Despite the challenging investment climate facing some smaller network operators, the 'alt nets' are also expected to invest significant sums in full fibre networks by 2030 and have already covered around eight million premises across the UK.³²³

At the current rate of deployment, the UK should reach the government's target to deliver nationwide gigabit capable coverage by 2030 (see Figure 3.6).³²⁴ However, reaching this target will depend on the government continuing its own programme to support connections in underserved areas and ensuring that a pro investment policy and regulatory framework remains in place. Improving take up rates will also be important. While take up rates are increasing, take up of gigabit capable networks at the end of 2022 was only around 38 per cent of premises passed, with take up of full fibre networks lower at around 25 per cent.³²⁵ Securing higher take up levels will be vital in ensuring that infrastructure firms can make a return on their investments.

Recommendation 25: Government should ensure that gigabit capable connectivity is available nationwide by 2030 by continuing to support network competition and market deployment, alongside delivering the £5 billion Project Gigabit programme to provide coverage to premises that are uncommercial.

Mobile connections

High quality mobile coverage allows people to access seamless connectivity inside and outside of the home and while on the move. 4G is the most widely accessed mobile technology in the UK today. While 4G coverage from all four UK mobile network operators now reaches 71 per cent of the UK landmass,³²⁶ coverage remains poorer in some areas:

- Rural geographic coverage from all four operators is 68 per cent compared to 97 per cent in urban areas.³²⁷ Delivery of the Shared Rural Network agreement will be key to improving rural coverage – it aims to increase 4G geographic coverage from at least one mobile network operator to 95 per cent by 2025 and will provide additional coverage to 280,000 premises and 16,000 kilometres of UK roads.³²⁸
- Coverage along major rail routes remains poor. Passengers can struggle to maintain consistent connections needed for making calls, streaming videos or working online.³²⁹ Rail mobile coverage reporting is also limited, with the last study undertaken in 2019.³³⁰ However, the Department for Science, Innovation and Technology, as part of their Wireless Infrastructure Strategy, has asked Ofcom to develop options for better reporting.³³¹

More also needs to be done to improve reporting on consumer experience of connectivity. Ofcom coverage statistics are based on predictions rather than user data, but actual consumer and business experience may be different to reported coverage. Better reporting would enable consumers to choose the best contract for them and drive competitive pressures on operators to improve their coverage footprints.

5G is the latest generation of mobile communication technology, with the potential to provide more reliable, lower latency, higher speed and higher capacity connectivity.³³² These capabilities have the potential to improve productivity for business and industrial users. 5G has the potential to help UK firms to improve efficiencies through greater digitization and automation, provide more secure and resilient networks than previous generations of wireless connectivity,³³³ and support new working practices and uses, such as augmented or virtual reality. Seventy-six per cent of premises can now receive non-standalone 5G coverage (where 5G radio access networks rely on a 4G core) from at least one operator.³³⁴ Higher quality standalone 5G networks (which rely on cloud based 5G core networks) have started to be deployed in 2023, with Vodafone launching standalone networks in several major cities.³³⁵

Government should encourage a market led approach to 5G rollout. This is based on evidence that:

- Industry will deliver 5G networks across populated areas of the UK without the need for subsidised rollout in the near term. Work by Analysys Mason carried out for the Commission estimates that delivering 5G networks to urban and suburban areas would cost just under £9 billion across all four operators by 2032.³³⁶ Other studies have reported that the mobile industry plans to invest £9 billion in 5G networks by 2030.³³⁷ While the Commission recognises that the investment climate for new mobile networks is challenging, competition between operators and announced plans for further rollout indicate there will continue to be significant network investment over the next decade.³³⁸
- Despite the potential benefits of 5G, there is not yet a case for public funding due to the present lack of strategically important use cases. Many uses can currently be supported by other telecoms technologies (such as 4G or WiFi), although this may change as later 5G standards are released and if new use cases emerge. Without clear indication of future demand, government intervention too early in network rollout risks delivering a 5G network that may not be suited to the UK's future needs.

The government's Wireless Infrastructure Strategy supports a market led approach to deployment. It aims to strengthen the investment environment for 5G and has adopted an ambition for nationwide standalone 5G coverage to all populated areas by 2030.³³⁹ To help industry to meet these aims, the government should focus on removing barriers to deployment.

To ensure recent changes to planning rules covering mobile masts take full effect, more should be done to standardise the application of new rules, improve engagement between industry and local authorities, and ensure best practice. Recent changes to the planning process have enabled more mobile masts to be deployed within permitted development rights, but prior approval from planning authorities is still needed. Prior approval rates vary widely between different local authorities leading to significant delays in some areas. Local authorities with digital champions, who lead on digital infrastructure strategy and promote the benefits of improved connectivity, generally have better approval rates.³⁴⁰ The government should provide

further support for digital champions to break down barriers to deployment, and should also explore ways to incentivise better engagement from local authorities, including collecting and publishing data on the best and worst pre-approvals rates compared with the coverage and quality of mobile networks in those areas.

Businesses should be enabled to deploy localised private networks through better access to radio spectrum, a portion of the electromagnetic spectrum which supports wireless communication. Localised private networks – dedicated networks for specific users – offer users higher capacity, tailored services providing the full benefits of a 5G network. This will be important in supporting 5G uses in the enterprise and industrial sectors, such as automation in ports and factories. Currently, many private 5G networks access radio spectrum through Ofcom’s shared access licence regime.³⁴¹ The regime allows access to spectrum in four specific spectrum bands for low or medium power licences,³⁴² with low power licences allowing any number of base stations within a 50 metre radius and medium power licences coordinated on an individual location basis. Ofcom is currently consulting on the existing process and expects to conclude its review early next year.³⁴³

The Commission supports the approach Ofcom has taken to allow shared access licences, which is one of the first such regimes in the world. Nevertheless, there are several restrictions on these licences which constrain their use and the application process can be burdensome. There may be good reasons for restriction on the power levels for shared access licences, for instance to avoid interference. However, the government and Ofcom should, where possible, seek to maximise use of this spectrum and look for opportunities to improve the efficiency of the application process, including through increased automation.

The government should also consider whether funding may be required to support nationwide 5G coverage in the future and be prepared to act fast if it is needed. Subsidised rollout has been required for previous generations of mobile technology, such as the 4G Shared Rural Network. While the Commission does not think subsidy will be needed over the next five years, there is a high level of uncertainty in predicting when and where new demand will emerge. It is possible that demand for 5G services may emerge from new use cases such as remote healthcare or agriculture, requiring wide area networks across all parts of the UK. Delivering the networks needed to support these uses may be uncommercial for the market alone but could bring wider benefits to the UK.

Recommendation 26: Government must ensure the right conditions are in place to accelerate the market led deployment of 5G. By the end of 2025, government should:

- **improve the consistency of approvals for 5G masts by planning authorities, including by allocating funding for local authority digital champions and publishing a list of the best and worst performing local authorities for site approvals**
- **work with Ofcom to encourage further use of the Shared Access Licence regime to speed up access to spectrum and open up opportunities for new services, including where increased power may be needed in some locations, and to ensure it supports localised private networks**
- **develop options for subsidising 5G coverage in uncommercial areas, should new use cases demonstrate the need for nationwide coverage.**

Digital's role in supporting other infrastructure sectors

Infrastructure owners and policy makers need to embrace digital technologies to prepare for the key challenges facing their sectors. Telecoms networks can help improve the efficiency and operational management of networks, help reduce emissions, ensure critical functionality and support innovative new uses. Digital connectivity can enable a greater number of sensors to be deployed across networks, leading to better monitoring and active management solutions, including the adoption of tools such as digital twins. Smart systems will be essential to meet targets for energy decarbonisation enabling the energy sector to reduce the costs of the network through the emergence of a smaller grid, and allowing smart grids to balance electricity supply and demand in real time as far more assets are connected. In transport, high quality wireless networks will help deliver the full functionality of new technologies like connected and autonomous vehicles.

Figure 3.7: Telecoms infrastructure will be vital to delivering critical functionality and strategic objectives across multiple sectors

Potential benefits of telecoms infrastructure across sectors

Support critical functions

2G railway signaling system needs to be upgraded to 5G by 2040

Energy network recovery will need ultrareliable low latency connections

Enable innovation

Connected and autonomous vehicles will be enhanced by advanced wireless connectivity

...to provide access to up-to-date maps and traffic information

Improve efficiency

Better sensor networks across all sectors can improve monitoring and maintenance to:

...enable tools like digital twins

...enable the rollout of smart water meters

...and to improve demand-side response i.e. flattening peak demand

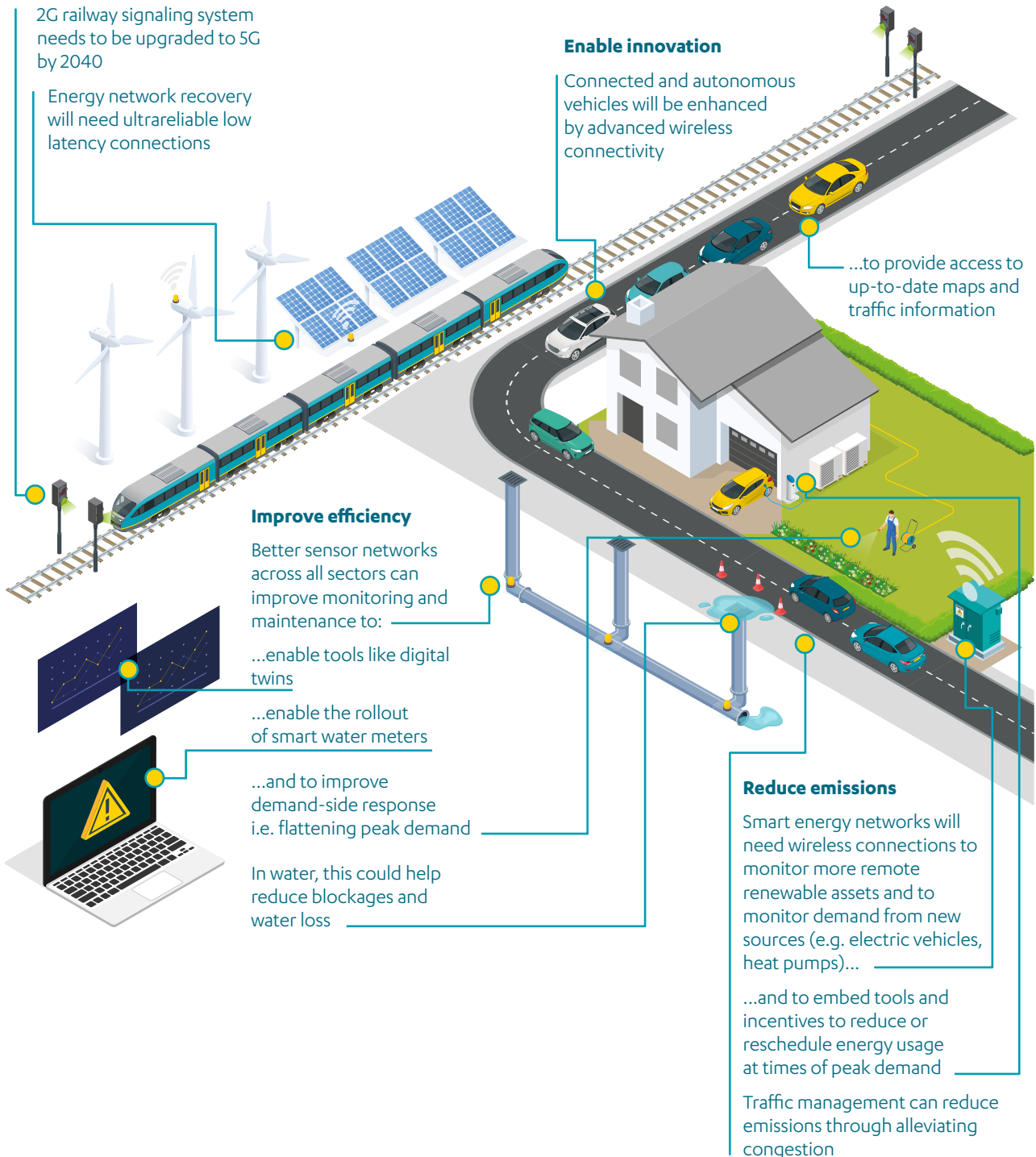
In water, this could help reduce blockages and water loss

Reduce emissions

Smart energy networks will need wireless connections to monitor more remote renewable assets and to monitor demand from new sources (e.g. electric vehicles, heat pumps)...

...and to embed tools and incentives to reduce or reschedule energy usage at times of peak demand

Traffic management can reduce emissions through alleviating congestion



Source: Commission analysis

Infrastructure providers should also consider how technology can enable demand management solutions and nudges to support behaviour change among consumers. Providers should encourage take up of services like smart meters and support demand reduction through pricing initiatives or other incentives.

The potential benefits of digitising infrastructure sectors are substantial but delivering the necessary digital infrastructure will take significant time and investment to achieve. More needs to be done to establish what telecoms networks are needed and how these should be delivered. Networks are likely to need a mix of different technology to deliver the right levels of coverage and resilience, including fixed networks, 4G and 5G, and in remote areas possibly satellite technology. Options for delivering such networks include the public mobile networks, dedicated private networks, or hybrid public/private solutions. The design of these networks will need to be determined by quality of service, resilience requirements and costs.

While the Commission has not undertaken a full analysis of different options, work undertaken by Analysys Mason to support the Assessment estimates that dedicated 5G networks to support operational uses for the road and rail sectors would cost around £1.5 billion, and for the gas and electricity sectors would cost around £820 million.³⁴⁴

The government has a clear role to play. Where infrastructure budgets are set centrally by government, such as for transport, these may need to be increased to cover dedicated digital networks. Alternatively, government may need to provide subsidy for the mobile network operators to expand their networks into underserved areas in order to support infrastructure uses. If subsidy is needed to expand the public mobile networks to support infrastructure uses, this may also expand mobile coverage into more remote areas. Government should consider whether any increased mobile coverage in remote areas will bring wider economic or societal benefit to the country as a whole.

Where telecoms infrastructure will be funded by sectors themselves (and ultimately bill payers), as may be the case for the utility and water networks, the government should provide clear steers to regulators on the importance of allowing investment to be recovered from regulated asset bases.

New telecoms networks may also require access to dedicated radio spectrum, for instance to support private networks offering a higher level of resilience than offered by public networks to support critical functions such as rail signalling or energy network recovery. Ofcom is already considering which spectrum bands may be most appropriate for the rail and energy sectors, but it has made clear that it is for the government and sector regulators to determine whether a private network(s) is required for the utilities sectors.³⁴⁵

The government should consider the potential for different sectors to share telecoms infrastructure. If dedicated networks are required – for example due to the need for higher resilience requirements – there may be significant benefits from infrastructure sectors sharing networks, including reduced costs and more efficient use of spectrum. There may also be opportunities to deliver additional public policy goals through infrastructure upgrades or rollout. For instance, it is possible for the 5G rail signalling upgrade to support enhanced rail passenger connectivity alongside improved operational uses and critical signalling.³⁴⁶ The government should consider the cost and feasibility of delivering rail passenger connectivity through the 5G Future Railway Mobile Communications System upgrade.

As with any areas that cut across sectors, unclear policy ownership could undermine delivery. It is essential that responsibilities within government are clear. Departments with responsibilities for each infrastructure sector should determine the connectivity and resilience needs of those sectors and work with their sectors to ensure those needs are met. The department responsible for digital infrastructure (currently the Department for Science, Innovation and Technology) has a clear role to join up these policies and to consider opportunities for infrastructure sharing across sectors.

The next five years will be key for making decisions about the future telecoms needs of infrastructure sectors. The energy sector is working to tight timelines to reach targets to decarbonise UK power by 2035. To meet the 2040 deadline to replace the 2G rail signalling system with the 5G Future Railway Mobile Communications System upgrade, funding and specifications for the new rail signalling system need to be established over the next few years. Ofcom has also made clear that, dependent on the band, reallocating spectrum could take upwards of five years. Plans for telecoms infrastructure will also need to be included in funding settlements as part of the relevant regulatory settlements and control periods coming up across the energy, water and transport sectors in the next few years.

Recommendation 27: Government should identify the specific telecommunications needs of the energy, water and transport sectors and ensure that infrastructure is delivered to meet these by, at the latest, 2030 for the energy and water sectors and 2035 for the road and rail sectors. Strategies for how this will be achieved must be set out by the end of 2025 for energy and water and by the end of 2026 for road and rail, including:

- **the most cost effective network deployment models, and the extent to which infrastructure can be shared between different sectors**
- **a spectrum authorisation approach that ensures access to adequate spectrum, whether dedicated national bands or shared spectrum for infrastructure users**
- **clear responsibilities within government for delivering telecoms strategies**
- **consideration of whether dedicated networks and spectrum or upgrades to existing networks can meet specific public policy goals, including consistent and reliable rail passenger connectivity.**

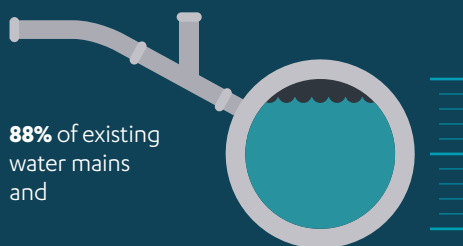
4. Improving resilience and the environment



Infrastructure needs to be resilient to climate change, while it can also help enhance the environment

Infrastructure assets have long lives, so climate resilience needs to be built in now

Based on current rates of replacement



85% of rail assets



could still be in place by 2055

Action is needed to secure long term water supply

The estimated supply gap by 2050 is at least **4,000 Mega litres per day (Ml/day)**

An approach which reduces demand and leaks, and increases supply, is required:

New supply and transfer infrastructure like reservoirs – at least **1,300 Ml/day**

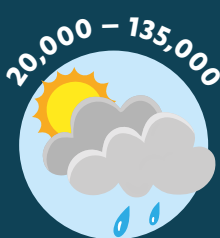
Halving leakage through continuing progress in line with industry commitment – **1,400 Ml/day**

Reducing demand through measures such as smart meters and public awareness raising – at least **1,400 Ml/day**



Surface water flooding is a growing problem which will need new infrastructure to solve

325,000 homes are already at high risk of surface water flooding, By 2055, this could increase by:



due to
climate change



due to
new development



due to increases in
impermeable surfaces



Investing c. **£12bn** in cost effective improvements to 2055 could reduce properties at high risk by **60%**

To lessen environmental impacts and reduce emissions, waste must be reduced

To meet climate targets, household recycling rates in England must rise from **44%** now to **65%** by 2035



Sources: Defra, Sayers et al, Commission modelling

Infrastructure and the environment are interdependent. Infrastructure reliability is threatened by environmental risks, while infrastructure systems can also affect the environment. The UK needs infrastructure systems which are resilient to future challenges including environmental threats like climate change. At the same time infrastructure systems need to be built and operated to repair past damage to the environment and deliver environmental improvements in the future.

The UK's infrastructure has proved fairly resilient over recent decades, but faces increasing exposure to shocks, including from the environment. Government should publish outcome based resilience standards by 2025 to inform future regulatory settlements and infrastructure operators' climate change adaptation plans.

The UK will need new assets to adapt to climate change. Government should invest long term in enhanced flood risk management infrastructure to reduce the risk of coastal, river and surface water flooding, and set clear targets for risk reduction. The Commission recommends government commit to a long term stable programme of investment in flood risk management over the next 30 years.

To improve resilience to droughts, government and industry should follow a twin track approach, managing water demand and increasing supply. Reducing demand, including leakage, and building water supply infrastructure will require additional investment and must be properly funded in the upcoming and subsequent price reviews.

All new infrastructure should deliver environmental improvements, but some sectors can go further. Government should build on its commitment to biodiversity net gain. It can do this by requiring sectors with the biggest potential impact — transport, water and flood risk management — to deliver improvements to both biodiversity net gain and environmental water quality when investing in maintenance and renewal of existing assets, as well as in new infrastructure.

Improving environmental outcomes also means reducing the impact of wastewater on water bodies. Meanwhile, in the solid waste disposal sector, government should move faster to achieve its 65 per cent recycling target and incentivise recycling infrastructure that will be needed for a circular economy. Government should further reduce emissions through limiting demand for energy from waste which does not have carbon capture and storage.

The challenge ahead

The UK's infrastructure systems have proved fairly resilient over recent decades. Disruptions and failures have generally led to moderate impacts, rather than extreme or catastrophic ones. However, failures do happen and are becoming increasingly prominent in discussions about the UK's infrastructure:

- the Covid-19 pandemic response and storms in 2021 and 2022 demonstrate that system designers often don't fully consider the impact of the failure of one system on others. The Climate Change Committee found that only 31 per cent of infrastructure operators had a good understanding of interdependency risks and plans to manage them.³⁴⁷
- the UK's failure to build storage capacity into energy networks left it particularly exposed to the 2022 energy crisis. Without government support, itself a cost to taxpayers, the average household's energy bill could have more than trebled.³⁴⁸
- the summer 2022 drought reinforced the need to ensure water supplies are more resilient to the growing risk of climate change.

Resilience often requires spare capacity in networks. This can cost money in the short term but avoid costly impacts over the longer term. The Commission's analysis found 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.³⁴⁹ As Chapter 2 highlights, establishing a strategic energy reserve would come at a cost but would reduce exposure to future price shocks. However, many resilience 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 cycles, and through service standards which have public backing. This will limit the impact of shocks and support recovery, so disruption from events doesn't lead to major harm.

Resilience will involve ensuring that existing systems can withstand shocks. It will also mean managing uncertainty to adapt to changing threats. The Commission's proposed investment in surface water flooding is robust to a range of future climate scenarios. New infrastructure will also be needed to ensure drought resilience. Delivering resilience needs to strike a balance between those who pay now, and future generations who may pay increased costs due to inaction.

Alongside making infrastructure more resilient, it should also be designed and delivered in ways that prevent damage to, and improve the condition of, the natural world. The environment is under threat — between 1970 and 2021, 19 per cent of terrestrial and freshwater species in the UK decreased in abundance. Sixteen per cent of species in Great Britain are also threatened with extinction.³⁵⁰

Environmental water quality needs to be improved alongside wider environmental improvements. While environmental water quality has improved in recent decades, significant issues remain.³⁵¹ The number of serious pollution incidents caused by water company assets remains unacceptably high. Moreover, in 2021 only 16 per cent of water bodies achieved good ecological status.³⁵² In the waste sector, stagnant recycling rates mean further exploitation of natural resources.³⁵³ Sending waste to landfill or energy from waste plants also contributes to carbon emissions. To address the environmental crisis, infrastructure with the biggest potential to support environmental enhancement needs to deliver as much environmental improvement as possible both when commencing new projects and when operating, maintaining and renewing infrastructure.

Improving resilience

Resilient infrastructure can continue to provide the services that businesses and communities rely on despite short term shocks. It can also adapt and transform to longer term chronic stresses, risks and opportunities. The Commission has identified six key aspects of resilience: **anticipate, adapt, resist, absorb, recover** and **transform**. In determining levels of resilience, government will need to consider the right balance between the costs of resilience, impacts of disruption and consumer expectations, to determine the 'level of service' to aim for across infrastructure sectors. This will include striking a balance between under and over investing in resilience. Where more resilient infrastructure can **anticipate** and **resist** or **absorb** shocks, it can prevent economic damage by improving the reliability and predictability of services. Where it cannot, a focus on fast **recovery** can improve quality of life and reduce disruption costs.

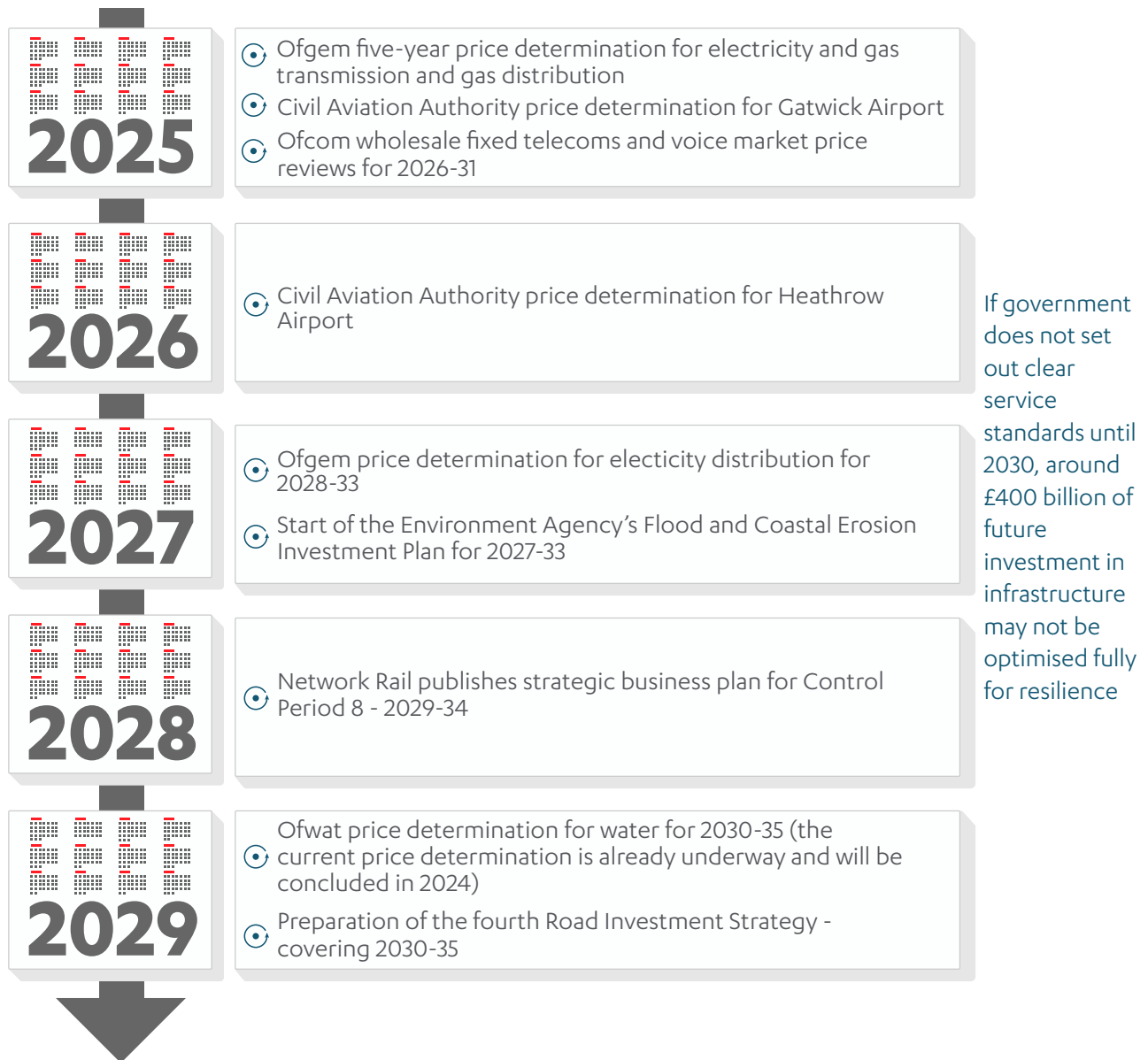
Resilience can be specified through a set of outcome based resilience standards that are regularly reviewed. In some sectors these already exist. In the energy sector, distribution companies have 12 hours to restore electricity supply if it fails in normal weather conditions.³⁵⁴ Similarly, the water sector has adopted the Commission's recommendation to make water supplies resilient to a drought with an annual probability of 0.2 per cent. However, there is significant variation in how government provides standards for infrastructure. Even where standards exist, they will need to be reviewed to ensure they remain affordable, appropriate and acceptable, particularly in a changing climate. To have force, these standards should be reflected in regulatory settlements for infrastructure sectors to embed resilience into the system. Infrastructure systems will need to be subject to regular stress tests to ensure standards are being met. Stress testing should also consider interdependencies with other sectors to identify potential cascade failures.

Resilience also depends on understanding the condition of assets. As the Commission noted in its recent advice to Ofwat, it is important to use future focused asset health measures to understand how asset systems will perform in future, rather than focusing on how assets have performed in the past.³⁵⁵ This information will also inform effective operation, maintenance and renewal strategies. As the Commission has highlighted elsewhere in this Assessment, effective maintenance of existing assets and systems, such as road and rail, should be prioritised above enhancements.

Current government action on resilience is insufficient. The government has committed to publishing resilience standards by 2030, but this will miss the next round of regulatory cycles set out below.³⁵⁶ This means, for example, that the standards would not drive much new investment in asset resilience in the water sector until the 2034 price review. Without government setting targets to ensure resilience is properly valued, both the public and private sectors are unlikely to adequately invest in it. The lack of resilience will continue to be uncovered through system failures. Only by setting standards and embedding them in regulatory frameworks can progress be made on understanding their affordability and ensuring they are being met.

Figure 4.1: Regulatory processes are ongoing

Regulatory processes due to take place between 2025-29



Source: Commission analysis

Recommendation 28: By 2025, government should:

- following advice from regulators, publish a full set of outcome based resilience standards for energy, water, digital, and transport 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.

Managing assets in a changing climate

The first step in ensuring service resilience is understanding the existing infrastructure asset base. Many existing infrastructure assets have long lives and need to provide a resilient service into the future. For example, Network Rail currently replaces its assets at a rate of 0.5 per cent per year. If this is sustained, 85 per cent of existing rail assets will still be in place in 2055.³⁵⁷ Similarly, in Ofwat's current price review period, companies were funded on the basis of plans to renew an average of 0.4 per cent of water mains per year. If this is continued, 88 per cent of existing mains will still be in place by 2055.³⁵⁸

While in many sectors the assets will largely remain the same, the climate will be different, and assets often are not resilient to current climate risks. This is partly due to a historic failure to anticipate risks and understand the underlying health of assets. In 2022-23 Thames Water experienced a year on year increase in leakage despite a long term target to reduce it. The company stated that this was partly because the drought of summer 2022 led to ground movement, causing pipes to burst.³⁵⁹ A changing climate can also contribute to acute failures. In 2019, heavy rain threatened the integrity of a canal network reservoir dam in Derbyshire, resulting in the temporary evacuation of 1,500 people.³⁶⁰ While this event cannot be definitively attributed to climate change, heavy rainstorms are projected to become more frequent in future. In sectors such as energy, where many new assets will be needed to achieve the net zero transition, infrastructure operators must ensure that resilience against a changing climate is built into new systems.

Asset and system resilience will be tested in a changing climate. Risks include drought related subsidence damaging underground networks, heavier rain causing flooding and embankment failures, and more frequent extreme heat affecting surface transport.³⁶¹ Additionally, low likelihood but high impact events heighten the risk of unforeseen cascade failures, where failures in one system adversely affect another.³⁶²

The Climate Change Act 2008 gave government the power to require infrastructure operators to produce climate adaptation reports.³⁶³ There have been three rounds of these reports to date with a fourth due in 2024, though the government has decided they should be voluntary rather than mandatory. The reports set out how infrastructure systems will be adapted in the face of future climate change. The last round of reports set out some of the costs of individual climate threats, but very limited information was provided on the costs of adapting systems to maintain service resilience in the face of threats. Additionally, industry stakeholders the Commission engaged reported that the cost of adaptation was a key knowledge gap across all sectors. There are different levels of preparedness for adaptation both within and between sectors. In the transport sector, Network Rail is planning to invest £1 billion in adaptation in their next investment period (2024-29).³⁶⁴ It is also planning to develop a costed climate investment programme based on adaptation pathways by 2029.³⁶⁵ But in most sectors long term costed adaptation plans do not yet exist.

To have a debate about whether current service levels are affordable, feasible or socially acceptable in a changing climate, government and the public need to understand their projected costs and implications for people's lives. For example, making rail lines resilient to hot weather could require an expensive rail retrofit programme. Government should decide

whether the cost is acceptable or whether standards should be downgraded to allow for slower trains on hot days, considering all societal costs. Infrastructure operators should be required to set out the costs of maintaining outcome based resilience standards in the face of climate change. After these standards are published in 2025, the costs should be used to inform subsequent regulatory settlements. They should then also be published in a compulsory fifth round of adaptation reports in 2029.³⁶⁶

Assessing the costs of climate resilience is not easy. Data gathering will be required to fully understand the impacts of current and potential future extremes on infrastructure systems. Infrastructure operators will also need to work with investors and contractors to ensure their plans are financeable and deliverable. But ongoing asset management should include ensuring systems are resilient to future risks, including climate change.

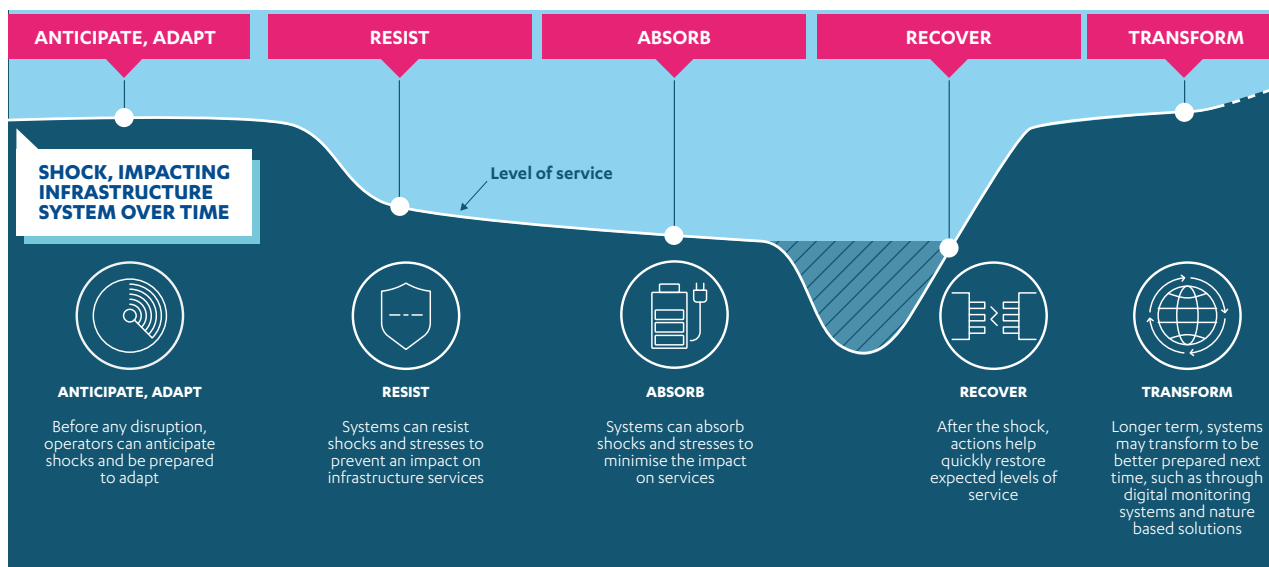
Government can address some of the barriers to assessing these risks. Industry has reported some challenges with using Met Office data to understand future climate scenarios.³⁶⁷ These include difficulties in accessing the information needed to assess the likely frequency of extreme events, which would enable a better understanding of the benefits of adaptation measures. If the best information on the frequency of extreme rainfall is readily accessible, it will be easier to estimate the likely damage it will cause and the value of protecting against it. Government should ask the Met Office, regulators and infrastructure operators to work together to fully understand how they use existing climate data and make it as accessible as possible. This could follow the model of the portal the Department for Transport and the Met Office are developing for the transport sector. It may be the case that the current climate projections, known as UKCP 18, include data gaps which mean they cannot be used to make some of these calculations. If this is the case, government should ensure these gaps are filled as soon as possible.

Stakeholders also report that many technical engineering standards for infrastructure assets are out of date, only requiring them to be resilient to current climate conditions. In the case of extreme heat, the Institution of Mechanical Engineers has called for an update of technical standards and design codes.³⁶⁸ Many organisations derive their technical standards and design codes from organisations such as the British Standards Institute or industry specific bodies such as the Energy Networks Association.³⁶⁹ Government should work with these bodies to update standards to include forward looking climate projections to enable climate resilience planning. Many of these standards are also derived from international standards, such as those produced by the International Standards Organisation. Organisations responsible for setting standards in the UK should continue their existing collaborations with these bodies to encourage the rapid development of forward looking standards.

Infrastructure operators will need to assess not only the resilience of their own systems, but also interdependency risks with other systems. Useful tools such as the Connected Places Catapult's climate resilience demonstrator can support this.³⁷⁰ The Commission's resilience framework illustrates how infrastructure operators can think about building resilience into their systems. As the examples below highlight, in some sectors there is already good practice which other infrastructure operators can learn from.

Figure 4.2: The Commission's resilience framework can be modified for climate resilience

Adapted resilience framework



Source: National Infrastructure Commission

Anticipate future risks: This includes understanding the age profile and quality of the asset base, as well as its maintenance history. Organisations should collect data on how assets will react to acute and chronic risks. Gatwick Airport is collecting this data through deploying remote condition monitoring.³⁷¹ Where extremes have been projected but are not yet experienced, asset operators should model potential impacts. Asset operators will also need to understand the relationship between asset performance and wider system performance.

Adapt: Organisations should develop asset strategies and procurement based on whole life cost, not what is cheaper in any given investment period. Where possible, organisations should develop adaptive pathways to adjust systems over time as the trajectory of future climate change becomes clearer. The Thames Estuary 2100 strategy uses review points to consider the strategy in light of more data about changing flood risk and how flood risk assets are performing over time.³⁷²

Resist: Where possible, networks should adopt a systematic approach to resisting shocks. The Energy Networks Association's Technical Report 138 requires that by 2028 substations that are serving more than 10,000 customers, whose supply cannot be switched to an alternative substation, have to be resilient to a flood with a 0.1 per cent annual probability.³⁷³

Absorb: Operators should understand how far systems can absorb shocks while maintaining services. This includes understanding interdependencies. Sometimes this may be a better strategy than just resisting a climate threat. For example, where risk remains high despite flood defences houses should be adapted so flood water does less damage, such as through raising electricity circuits and installing tiled flooring.

Recover: Services and communities should be enabled to rapidly recover. Insurance and community assistance are needed to help people recover from shocks as quickly as possible.

Transform: Operators should take opportunities to redesign systems while building resilience. These include making the most of existing infrastructure through building in digital solutions or introducing nature based solutions such as sustainable drainage.³⁷⁴ For example, a digital smart sensor network in sewer systems could alert operators to incidents in real time. This would allow them to make operational changes which prevent sewer spills, making better use of existing capacity and removing some of the need for new infrastructure.

Recommendation 29: In time to inform the next round of regulatory settlements (for water, digital and energy networks) or spending reviews (for road and rail networks and flood risk management infrastructure), government should ask infrastructure operators to estimate the costs of maintaining government resilience standards in the face of projected climate change to 2050. For sectors without formal spending settlements, such as ports and waste, these should be reported by 2029. All sectors should publicly report adaptation costs in a compulsory fifth round of Adaptation Reporting Power reports in 2029.

Recommendation 30: By the end of 2025 the Met Office, infrastructure operators and appropriate regulators should work together to develop an accessible interface for asset owners to use relevant climate data.³⁷⁵ In time to inform the fourth National Adaptation Plan and the fifth Climate Change Risk Assessment, government should consider whether another UK Climate Projection is needed to fill data gaps to support infrastructure operators in planning for climate adaptation.

Recommendation 31: By the end of 2026 government should work with the relevant standards bodies to identify and update core technical engineering standards to factor in future climate change.

Improving flood resilience

About 900,000 properties in England have more than a one per cent chance each year of being flooded by rivers and the sea. Around 910,000 properties have a more than one per cent chance of flooding from surface water.³⁷⁶ Floods affect people's lives and health as well as causing economic damage.

While it will never be possible to prevent all flooding, the current approach is piecemeal, and progress is hard to measure. In the Commission's social research for the Assessment, respondents had relatively low confidence in flood risk management. It was the lowest scoring sector within the Commission's remit in terms of public confidence, 20 percentage points below any other.³⁷⁷ The government has increased investment in flood risk management in line with the recommendations in the Commission's first Assessment and the current investment round plans to better protect 336,000 properties. Yet there is no measurable long term national target to reduce flood risk beyond the current investment round, and the current target does not factor in risk increasing due to climate change.³⁷⁸

The Commission has assessed surface water flooding and flooding from rivers and the sea:

- surface water flooding — also referred to as pluvial or flash flooding — happens when there is so much rain that it cannot drain away quickly enough, either because drainage networks reach capacity and overflow, or because they are not operating at full capacity due to blockages in pipes and sewers, or in above ground drainage like gullies
- river flooding happens when long periods of heavy rainfall cause rivers to inundate their floodplains
- flooding from the sea is usually caused by storm surges at high tide.

Both river and coastal flooding can be particularly serious when flood defences, which protect people and buildings, fail. The risk from all of these forms of flooding will increase as the climate changes. Measurable long term national flood risk reduction targets for all types of flooding would drive action.

Surface water flooding

Climate change and population growth will both increase surface water flood risk unless there is further action to manage risk. The Commission's surface water flooding study identified around 325,000 properties are in areas at high risk of surface water flooding. Climate change and population growth leading to new development could increase this by up to 70 per cent to 550,000.³⁷⁹ Additionally, increases in impermeable surfaces, which lead to an increase in surface water runoff, could increase risk by up to 20 per cent. Government has committed to consult on implementing Schedule 3 of the Flood and Water Management Act 2010, which requires new developments to provide their own surface water drainage, avoiding this risk. It should implement Schedule 3 as soon as possible.

Responsibility for managing surface water flood risk is split. Upper tier local authorities manage risk through local authority assets, such as surface drainage channels. Separately, water companies manage the risk of flooding from their sewers. As a minimum these assets should be adequately maintained and managed to avoid blockages. While the two sides have a duty to cooperate, greater coordination is needed as funding and incentives remain divided.³⁸⁰ At a national level there is a need for the Environment Agency to expand its strategic oversight role in relation to surface water flooding, including identifying high risk areas. At a local level upper tier local authorities, water and sewerage companies and, where relevant, Internal Drainage Boards, should then develop and deliver long term, costed, joint plans, setting out local targets for flood risk reduction. Funding to local authorities for surface water flood risk management should be devolved to support this. Joint working should include data sharing to inform the most appropriate interventions to manage flood risk. This should also be fed into the Environment Agency's national flood risk model to enable greater understanding of the areas which are most at risk.

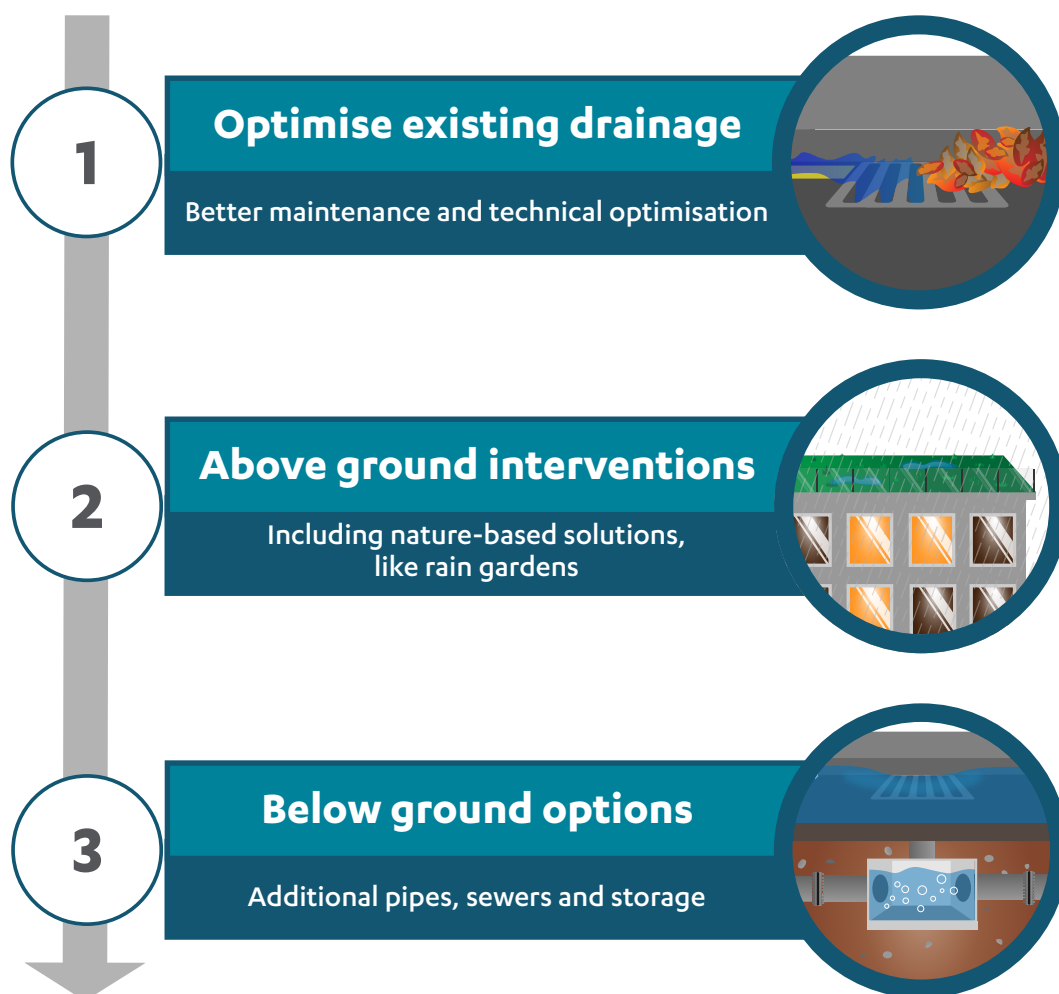
A national target for flood protection is required before determining what can be achieved at a local level. Protecting all properties is not feasible. Surface water flooding can be unpredictable and highly localised, meaning flood risk management infrastructure doesn't benefit from the same economies of scale as those for coastal and river flooding. For many properties, new flood risk management infrastructure would cost far more than the damage caused by floods. Modelling for the Commission's study on surface water flooding suggests that investing in drainage infrastructure measures where the benefits outweigh the costs could reduce the

number of properties at high risk by 2055 by around 60 per cent — at a total investment of £12 billion. This is £3.6 billion more than would be expected if combined current water company expenditure and Environment Agency funding was maintained over the next 30 years.³⁸¹ This highlights the need made clear elsewhere in this Assessment for greater investment in infrastructure. Although this investment level is based on the upper end of the Met Office's UK climate projection scenarios, it would still deliver benefits even in the more optimistic climate scenarios. The actual future increase in rainfall in different climate scenarios is uncertain and so it will be important to be robust to a range of scenarios. This approach can be adapted over time, with the investment strategy amended as more information about future rainfall patterns becomes available. This means £12 billion would be the upper end of the potential spend, and based on current proportions around 60 per cent of this would come from water companies.³⁸²

To deliver multiple benefits, as well as efficient investment, surface water flooding infrastructure should follow the hierarchy in Figure 4.3.

Figure 4.3: Surface water flood management should only consider below ground interventions after other options have been explored

Surface water flood risk reduction intervention hierarchy



Source: National Infrastructure Commission

The Commission's modelling suggests that, even after these interventions, 40 per cent of properties currently at high risk of surface water flooding could remain so. Even when impacts from flooding on quality of life are factored in, the benefits of infrastructure solutions do not outweigh the costs. This is particularly the case in rural areas.³⁸³ In these cases government should explore options for property level protection to improve resilience to flooding.

Recommendation 32: In relation to surface water flooding, government should progress measures to control the area of impermeable surfaces, accurately identify areas where the most properties are at risk and set a clear long term target to reduce properties at risk. The appropriate flood risk management authorities should develop single joint plans to deliver the reductions in risk. These plans should be supported by devolving funds from national budgets with local public and private contributions, particularly from water companies where their assets need to be improved to reduce the risk.

Full details of the recommendations can be found in Reducing the risk of surface water flooding³⁸⁴

Flooding from rivers and the sea

The government is investing £5.2 billion in flood and coastal risk management between 2021 and 2027.³⁸⁵ This is broadly in line with the Commission's recommended level of funding. This should be a rolling programme with funding remaining at similar levels to 2055. However, as with surface water flooding, the government currently has no quantifiable long term risk reduction target for flooding from rivers and the sea beyond the current investment cycle. Without this, it is not possible to measure whether government is making sufficient progress in reducing overall flood risk. Setting a target level of risk reduction would allow the Environment Agency to take a transparent strategic approach across catchments, publicly setting out the areas that are most at risk and delivering improvements there first. Government could use its update to the National Flood Risk Assessment model and Long Term Investment Scenarios to set out the number of properties for which flood risk will be reduced over the long term. The level of protection that can be achieved will depend on the local context in which a scheme is developed and in particular, the social and environmental impact that such infrastructure may have. Climate change is likely to require larger schemes over time to maintain the same level of protection.³⁸⁶

Analysis for the first Assessment suggested that it would be cost effective overall to substantially reduce the number of properties with a greater than 0.5 per cent annual probability of flooding. It also suggested that substantially reducing the number of properties with a greater than 0.1 per cent annual risk is affordable in major cities due to population density. An extreme flood in an urban area could overwhelm emergency services, with the potential for serious societal impacts.³⁸⁷ These levels of protection remain an appropriate starting point for discussion about the national investment level to reduce the risk of flooding and as the starting point for an appropriate standard of protection to be achieved locally. However, more detailed local analysis of flood risks and costs may indicate that different standards are justified. Protection to **resist** flooding will be a key aspect of any approach to flood risk reduction, but it is only part of wider resilience, including actions by the Environment

Agency and emergency services to warn and evacuate, along with strategies to assist recovery. A wider consideration of resilience will also enable solutions tailored to the needs of local communities. For example, rather than building flood defences which obscure views of waterfronts, communities may prefer timely warnings to prepare for floods and adapted buildings to improve recovery times.

New development should not be allowed to increase the number of properties at risk of flooding. This can be achieved by locating new development in low risk areas, and requiring developers to achieve a suitable level of flood protection and not to increase the risk elsewhere. Since the first Assessment, the government has taken stronger action, requiring new development to resist coastal floods with a greater than 0.5 per cent annual probability and river and surface water floods with a one per cent annual probability.³⁸⁸ It should go further by requiring all new development to be able to resist river and surface water floods with an at least 0.5 per cent annual probability.

The approach to infrastructure should follow a similar hierarchy to surface water flooding. Nature based solutions deliver multiple benefits and should be considered first. Ofwat has taken steps to support this by changing how nature based solutions are accounted for by water companies. Any approach also needs to be adaptive to manage uncertainty. It is unclear how much flood risk will change in future so where possible flexibility should be built into schemes to avoid expensive retrofits.

Recommendation 33: By 2025, government should set a long term measurable target to reduce the number of properties likely to be flooded by rivers or the sea. Progress against this target should be tracked using the Environment Agency's new National Flood Risk Assessment and take account of property level protection.

In setting and delivering the target, government should:

- **use as a starting point the Commission's proposed standard of protection against flooding of an annual likelihood of 0.5 per cent and 0.1 per cent for densely populated areas**
- **make use of National Flood Risk Assessment 2 and future iterations of the Environment Agency's Long Term Investment Scenarios to quantify risk and establish targets for cost effective risk reduction**
- **adopt different standards of protection in local areas, where cost effective and based on discussions with affected communities**
- **invest in line with the profile set out by the Commission**
- **maximise the use of nature based and catchment solutions and consider the additional benefits beyond flood mitigation that they bring**
- **adequately fund wider resilience measures to prepare for and recover from flooding**
- **require planning authorities to ensure that from 2026 all new development is resilient to flooding from rivers with an annual likelihood of 0.5 per cent for its lifetime and does not increase risk elsewhere.**

Managing the risk of drought

As the climate changes and the population grows, England will need to better manage its water supply infrastructure. July 2022 was the joint driest July on record in southern England, and only a wet autumn saved the country from facing serious drought conditions.³⁸⁹ Failure to manage changing needs for water resources will also inhibit growth. The government announced plans in July 2023 to accelerate water supply infrastructure in Cambridge because water scarcity is constraining potential housing and economic growth.³⁹⁰ The public are also increasingly concerned about environmental water quality, which water scarcity can exacerbate. If too much water is taken from the environment, low river levels will damage habitats. This will also mean any polluted discharges into rivers are less diluted, worsening their impact. Analysis for the Commission suggested that proactively preparing for a drought with a 0.2 per cent annual probability may cost half of the amount that emergency measures would cost. There is a six per cent chance of such a drought in the next 30 years.³⁹¹

The Commission recommends a twin track approach to drought resilience — increasing supply and managing demand. The projected gap between supply and demand is at least 4,000 megalitres per day by 2050. This is around 30 per cent of the water currently put into public supply.³⁹² At least 1,300 megalitres per day from new infrastructure will be required by the mid 2030s.³⁹³ No new large reservoirs have been completed in England for 30 years and water infrastructure is complex to deliver. As an indication of how the gap might be filled, draft Water Resource Management Plans propose nine new large reservoirs, two reservoir enlargements, three large intercompany transfers, 11 water recycling schemes and nine new desalination plants.³⁹⁴ As the Commission's recommendations on planning set out, there is a high risk of delay to the delivery of these projects. Funding and delivery must start as soon as possible.

In addition to increasing supply, the remaining gap should be met through reducing demand, by cutting leakage and water use by households and businesses. At Price Review 2019, water companies agreed to halve leakage by 2050.³⁹⁵ Up to March 2022, the latest set of consolidated figures, leakage was reducing in line with this target but there is still a long way to go.³⁹⁶ If achieved, the target will make leakage levels in England comparable with some of the best networks in Europe — a challenging but deliverable target.³⁹⁷

Finally, further action is required to reduce water use. The government has committed to a legally binding target of reducing consumption of water by 20 per cent per person by 2038, on a trajectory to reducing water use from the current level of around 145 litres per person per day to 110 litres per person per day by 2050. It has also committed to reducing non-household demand by 15 per cent by 2050.³⁹⁸ However, some water companies are not enabled to roll out meters on a compulsory basis, a key tool in managing demand.³⁹⁹ Smart meters in particular also help identify customer leaks, and could provide £4.4 billion of total societal benefits for a £2.5 billion investment.⁴⁰⁰ But smart meters and current planned government interventions, including developing minimum water efficiency product labels with minimum standards and considering water efficiency standards for new developments, will not be enough to meet the government's ambitious demand target.⁴⁰¹ Further measures could include flexible tariffs and education campaigns to help consumers understand their own consumption and the effect of water abstraction on the natural environment. Ofwat has introduced a water efficiency fund for Price Review 24 to support innovative measures to drive down demand.⁴⁰² Government and

industry should set out clear long term plans with timelines for bringing down demand alongside the smart meter programme and government proposals on water efficient homes and devices. If demand targets are not met, additional supply infrastructure will be required. It is important that adequate funding is allowed to support new water supply infrastructure and demand reduction in the Price Review 24 settlement and subsequent settlements.

Recommendation 34: Government and Ofwat should ensure plans are in place to deliver additional supply and demand reduction of at least 4,000 mega litres per day. Action to deliver this twin track approach should include:

- **the Regulators' Alliance for Progressing Infrastructure Development and Price Review process ensuring that at least 1,300 mega litres per day is provided by the mid 2030s through (i) additional strategic water transfers and (ii) additional supply infrastructure**
- **the water industry maintaining its objective to halve leakage from 2017-18 levels by 2050, with Ofwat agreeing five year commitments for each company (as part of the regulatory cycle) and reporting on progress**
- **the Department for Environment, Food and Rural Affairs enabling companies to implement compulsory metering beyond water stressed areas by 2025, by amending regulations as appropriate and requiring all companies to systematically roll out smart meters as a first step in a concerted campaign to reduce water demand to 110 litres per person per day and to reduce non-household usage by 15 per cent by 2050.**

Improving the environment

UK and global trends show that natural capital has declined in recent decades. The latest UK biodiversity indicators show declines in the status of threatened habitats and species, as well as increased pressure from invasive species.⁴⁰³ Infrastructure is not the only cause of biodiversity decline, but if assets are badly designed and operated, they can exacerbate this problem by fragmenting habitats and polluting the environment.⁴⁰⁴

The Commission's recommendations set out the infrastructure needed over the next 30 years to deliver net zero, drive growth across regions, and increase resilience. This will require new development, alongside changes to existing assets. Tackling climate change requires capital expenditure on new infrastructure with lower or no fuel costs: reinforced electricity grids, renewable generation schemes rather than large central power stations, and electric vehicle charge points. Adapting to climate change requires additional flood management and water supply infrastructure.

If infrastructure design and delivery is done well, it can contribute to the government's goal of improving the environment over 25 years.⁴⁰⁵ Ensuring that the development of infrastructure assets improves the environment by increasing stocks of natural capital has many benefits, including:

- creating and improving natural habitats for biodiversity, and increasing connections between habitats, which also enables species to adapt to climate change

- increasing the resilience of infrastructure services to environmental shocks, for example through natural flood management and replenishing ground water sources
- improving air and water quality, for people and other species.⁴⁰⁶

Given the scale of the infrastructure transformation required, community backing will be essential. By properly managing environmental impacts, infrastructure developers should reduce the risk of costly and lengthy appeals processes due to environmental concerns. The Commission considered these issues in its study of the infrastructure planning system.⁴⁰⁷

Infrastructure developers are currently expected to deliver cobenefits for nature by following the hierarchy below:

- **Avoid:** sites with irreplaceable habitats at site selection stage wherever possible. The greater role for integrated spatial planning proposed in the Commission's planning recommendations, including mapping sites with irreplaceable habitats, would support this.
- **Mitigate:** reduce the impacts of schemes on a specific habitat, for example, habitat creation schemes within solar farm developments.⁴⁰⁸
- **Compensate:** by enhancing the environment elsewhere — for example windfarms which deliver artificial nesting sites to compensate for potential impacts on seabirds.⁴⁰⁹

As biodiversity loss is hard to reverse, ensuring losses of high value natural capital are minimised and mitigated while also providing opportunities to enhance natural capital is a 'least regrets' option.⁴¹⁰

From 2025, government will require new nationally significant infrastructure projects on land to achieve biodiversity net gain, with habitats secured, managed and maintained for at least 30 years.⁴¹¹ Biodiversity net gain is an approach to development that leaves biodiversity in a measurably better state than before the development took place.⁴¹²

Considering natural capital in infrastructure building and maintenance

Given the threat to the natural environment, the Commission believes all new infrastructure assets should deliver environmental improvement. Environmental improvement can be measured by biodiversity measures but also by ecosystem services, such as flood protection and recreation, and environmental metrics, such as air quality.⁴¹³ There are further opportunities to enhance environmental outcomes through the operation, maintenance and renewal of existing assets in sectors with the biggest potential to drive improvements — flood management, transport and water. There are also opportunities to improve environmental outcomes in the waste management sector.

For the first time, the Commission has undertaken a quantitative and qualitative risk assessment of the impacts of its recommendations and the trajectory of future government policy across all sectors on air quality, environmental water quality and biodiversity. This risk assessment found that cutting carbon emissions and electrifying the energy system will deliver large improvements in air quality from all infrastructure sectors currently emitting pollutants. The government's proposed investments in wastewater infrastructure set out below will also improve environmental water quality from current levels.

However, some infrastructure development will have a detrimental impact on aspects of natural capital. The Commission's assessment is that the combined impact of its recommendations, background trends and future government policy in transport and flood management in particular would, without mitigation, have an overall detrimental impact on the environment through damage to environmental water quality and, in the case of transport, biodiversity.

However, the Commission has undertaken analysis of possible mitigation measures including spatial planning, applying the mitigation hierarchy described above, the statutory requirement for biodiversity net gain and good design incorporating cobenefits from the outset. The Commission is confident that, if implemented and well designed, these mitigations will ensure that environmental water quality, air quality and biodiversity are all improved as a result of its recommendations.

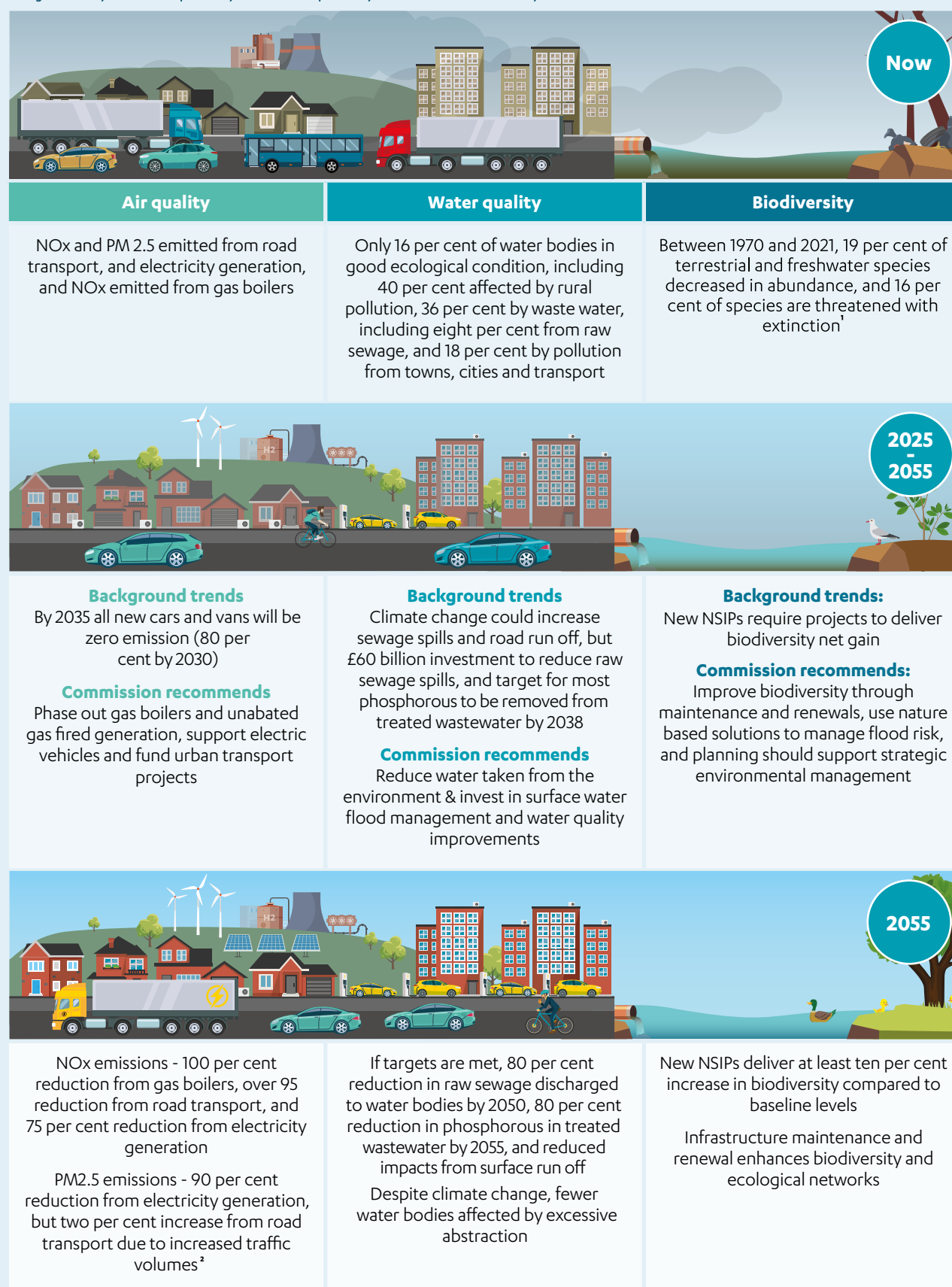
The Commission is continuing to develop its approach to natural capital to further understand how infrastructure affects, and can improve, the environment. While the Commission has undertaken a robust assessment of infrastructure's impact across sectors, it is making recommendations at a strategic level, so it is not able to set out precise impacts of schemes which do not yet have defined locations. Instead, schemes have a range of possible outcomes, and much will depend on how they are implemented. The infographic below sets out quantitative improvements which will be delivered by the Commission's recommendations and background trends including government policy. This is not exhaustive, as there are other potential benefits which cannot yet be quantified. The Commission will publish the details of its qualitative and quantitative risk assessment shortly.

If well designed, in some cases environmental improvements could be delivered at no extra cost.⁴¹⁴ Flood schemes could incorporate passages for fish, and road schemes could be designed to minimise rainwater runoff into water courses, which often has side benefits for resilience.

Given their potential negative impact on the environment, sectors with the biggest opportunity to have an impact can and should go further. The flood management, transport and water sectors should deliver biodiversity net gain and environmental water quality improvements through a strategic approach to conservation and restoration across their whole estate. This can be achieved by embedding biodiversity and environmental water quality improvements in operation, maintenance and renewal strategies for existing assets as well as for new assets. The costs of administration should be outweighed by benefits from improved delivery.

Figure 4.4: Environmental outcomes will improve through Commission recommendations and government action

Trajectory of air quality, water quality and biodiversity, 2025-55



¹ Infrastructure development is not the principal cause but can contribute to this problem

² This assumes electrification of the vehicle fleet is approaching 99 per cent in line with the Department for Transport's 'vehicle led decarbonisation scenario' and that gas boilers are no longer in use for household heating

Sources: National Atmospheric Emissions Inventory; Defra; Environment Agency; Commission analysis; Department for Transport National Road Traffic Projections 2022

Recommendation 35: Government should require infrastructure network and asset plans for the flood management, transport and water sectors to maximise the opportunity to improve natural capital by taking an integrated and strategic approach to maintenance and renewals. Infrastructure operators in these sectors should:

- **publish regular reports on the state of environmental water quality and biodiversity on their estates or affected by their assets**
- **develop and fund maintenance and renewal strategies that deliver a net improvement in environmental water quality and biodiversity by altering operating and maintenance regimes and materials, incorporating new design features reflective of nature based solutions, and in some cases moving spend from the development of ‘new’ to existing assets.**

Guidance and objectives should be delivered by:

- **the Department for Transport to inform National Highways’ Road Investment Strategies and Network Rail’s Control Period 8**
- **the Environment Agency as part of its enabling and supporting programmes included in the next Flood and Coastal Erosion Investment plan, due to start in 2027**
- **Ofwat working with the environmental regulators, to inform operation, maintenance and renewals activities in 2030-35.**

Improving environmental water quality

In recent years the impact of the water industry on the environment has attracted increasing attention. While environmental water quality has improved in recent decades, significant issues remain.⁴¹⁵ The number of serious pollution incidents caused by water company assets remains unacceptably high. Moreover, in 2021 only 16 per cent of water bodies achieved good ecological status.⁴¹⁶ The most common factors causing this are set out below. These factors overlap, meaning the same water body may be affected by more than one issue:

- **physical modification:** 41 per cent of water bodies have been modified from their original state for agricultural or other reasons, affecting water flow and overall quality
- **pollution from rural areas:** 40 per cent of water bodies are affected by pollutants such as agricultural runoff
- **wastewater:** At least 28 per cent of all water bodies are affected by wastewater impacts such as treated sewage discharges which can disrupt the nutrient balance in water bodies and increase water temperature
- **pollution from towns, cities and transport:** 18 per cent of water bodies are impacted by factors including misconnection of housing to surface water drainage systems and run off from road drainage systems in heavy weather⁴¹⁷
- **intermittent discharges, largely of untreated sewage:** Eight per cent of all water bodies are affected by intermittent sewage discharges, sometimes after heavy rain overwhelms the capacity of sewage treatment works.⁴¹⁸

The level of pollution from sewer overflows damages the environment and is unacceptable to the public. Public distrust is exacerbated by historic inadequate monitoring of the scale and length of spills. The government has set out a plan for private investment of around £60 billion to address the discharge of raw sewage over the next 25 years.⁴¹⁹ While progress must be made quickly, this should not come at the expense of the environment. Where possible, the industry should avoid traditional concrete storage solutions in favour of catchment based approaches which deliver natural capital benefits. Active underground network management could also regulate water flows to treatment works, making better use of existing assets.

Action on sewer overflows alone is not sufficient to secure the improvements needed to environmental water quality. The government has set a target of removing phosphorous from treated wastewater by 80 per cent by 2038 against a 2020 baseline.⁴²⁰ The government has also set targets on addressing water pollution from agriculture and abandoned metal mines. The Commission's recommendations on water resources will improve environmental water quality by increasing the volume of water available in the environment, diluting pollution impacts and supporting species. Investment in surface water flooding will also help to reduce pollution impacts from runoff from transport networks. Additionally, nature based solutions to flooding which follow the Commission's intervention hierarchy will improve the quality of water bodies.

The factors influencing environmental water quality are complex and often interrelated. The Commission is interested in contributing to work to understand how far a strategic programme of infrastructure investment can contribute to improving the health of England's water bodies. This could inform the government's planned review of its investments in sewer overflows by 2027.⁴²¹

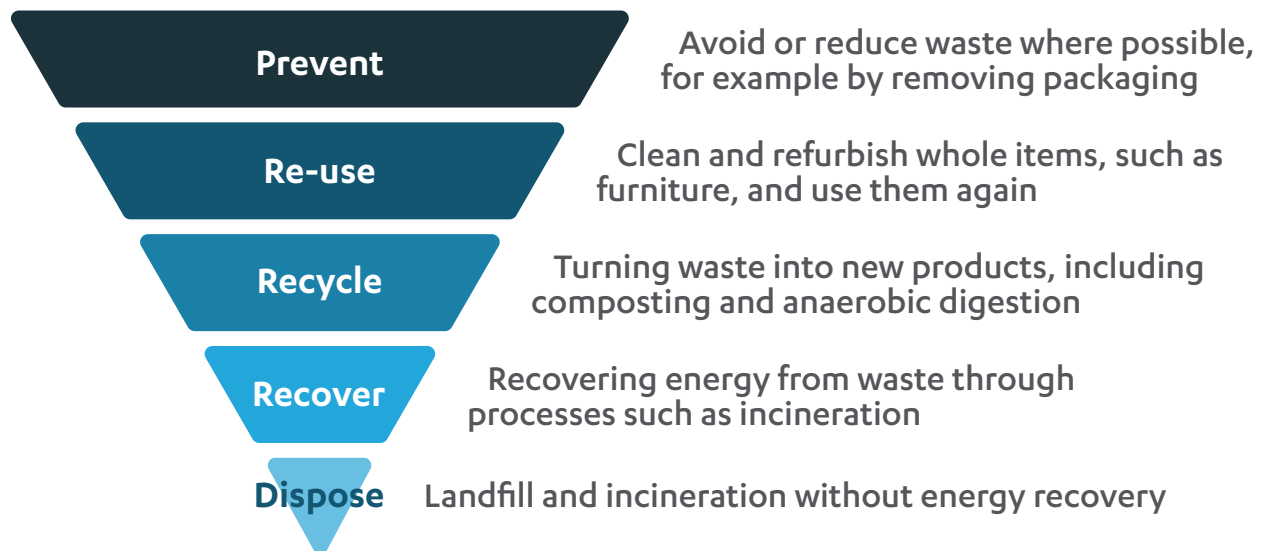
Resource efficiency and decarbonising the solid waste sector

Government action is needed to limit the waste sector's impact on the environment and achieve net zero. The more waste that is generated, the bigger the impact on the environment. The solid waste sector contributes around five per cent of the UK's carbon emissions.⁴²² The sector's emissions are not declining and recycling rates have stalled at around 45 per cent.⁴²³ The government has set targets to reduce waste, but current policies are delayed and insufficient. Government should implement its 'simpler recycling' proposals for a consistent set of recyclable materials across England, a deposit return scheme, and reforms to plastic packaging regulations. It should also support local authorities in driving up recycling rates. Finally, it should take strategic decisions on the future of energy from waste, to deliver a net zero waste sector with a reduced environmental impact.

To lessen environmental impacts and reduce emissions, waste should be pushed as high up the waste hierarchy, set out below, as possible. This means as much waste as possible is prevented and waste disposal is kept to a minimum.

Figure 4.5: As much waste should be prevented as possible, and waste disposal should be kept to a minimum

Waste management intervention hierarchy



Source: Environment Agency

The Commission examined three principal sources of waste – local authority collected waste, commercial and industrial waste, and construction and demolition waste. Waste sent to landfill or processed in energy from waste facilities without carbon capture produces greenhouse gases. Waste in landfill can also damage environmental water quality through leaching and energy from waste plants can affect air quality.⁴²⁴ The Commission's social research suggests the public support greater government action on recycling and greater producer responsibility for dealing with the packaging they produce.⁴²⁵

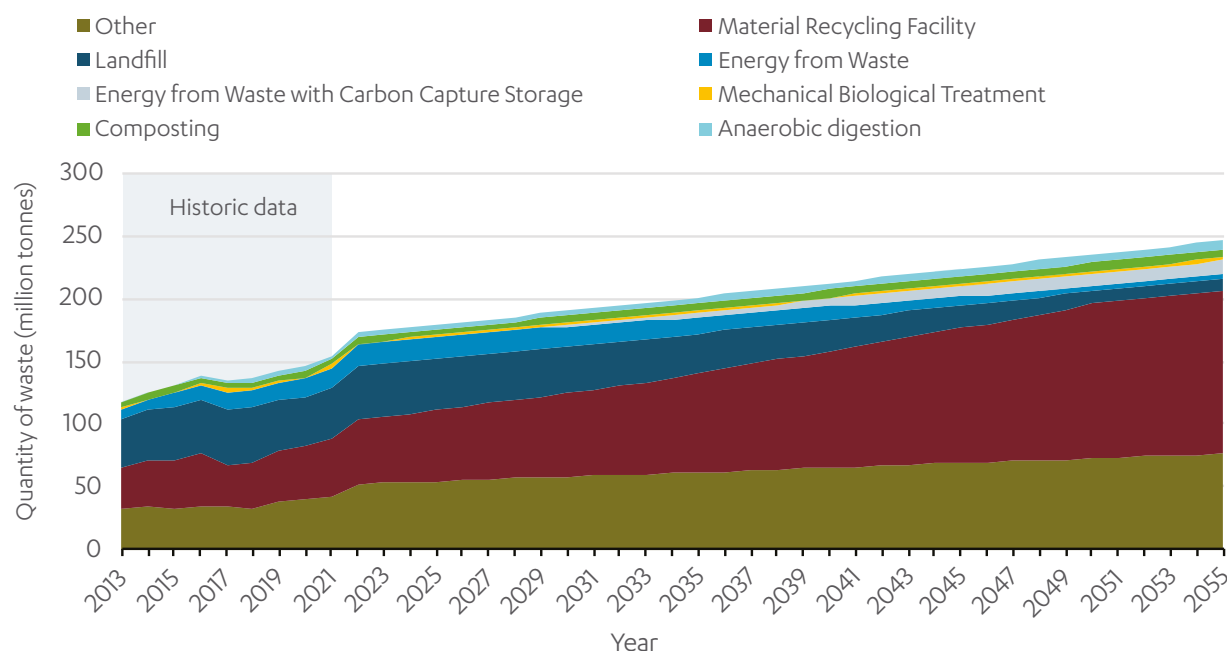
The government has set legal requirements to drive waste up the hierarchy:

- plans must be in place detailing measures to ensure 65 per cent of municipal waste, including household waste and household like waste from commercial and industrial sources, is recycled by 2035⁴²⁶
- the volume of residual waste per person which is not reused or recycled must be halved by 2042 from 2019 levels
- by 2050, avoidable waste must be eliminated by recycling or reusing any waste which possibly can be reused or recycled.⁴²⁷

These targets mean recycling rates will need to continue to improve beyond 2035. Meeting the 2042 target would represent a municipal recycling rate of around 75 per cent.⁴²⁸ Analysis for the Commission suggests that meeting the government's targets and delivering a net zero waste sector requires a significant increase in recycling infrastructure in the future.

Figure 4.6: A significant growth in recycling infrastructure capacity is required to meet net zero

Quantity of waste split by type of treatment



Source: Ricardo

Note: Recycling infrastructure is typically said to include material recycling facilities, anaerobic digestion and composting because processing through these facilities contributes directly to the measured recycling rate.

Waste infrastructure is funded by both the commercial sector and by local authorities, through arrangements including public private partnerships. To invest in this infrastructure, both local authorities and investors need clarity that there will be a suitable volume of waste of the right quality to make a given form of treatment plan profitable. The market is not currently delivering sufficient recycling facilities because policy uncertainty means investors do not know what volume or quality of material to expect. The value of waste sent for recycling is also relatively low. Seventeen per cent of recyclable materials are currently contaminated.⁴²⁹ Consistent recycling collections would increase demand for recycling infrastructure by reducing contamination rates and therefore increasing the quality and volume of materials that can be recycled. This would drive up the ultimate value of materials. It would also provide certainty on future stocks of available recycling, increasing investor confidence in the viability of recycling infrastructure and ensuring additional capacity is developed.

The government has taken some action. In April 2022 it introduced a plastic packaging tax, encouraging recycling by making new plastic more expensive.⁴³⁰ It also plans to introduce collection and packaging reforms. At the time of writing these included:

- 'simpler recycling' of a consistent set of dry materials for English households and businesses, at a minimum with separate food and garden waste collection for households
- a deposit return scheme where consumers receive money back for returning drinks containers
- extending producer responsibility for packaging so manufacturers pay the full cost of managing and recycling their waste.⁴³¹

Figure 4.6 demonstrates what could happen if the government implements these reforms and then achieves its subsequent targets. The sooner they are implemented, the sooner more waste can be recycled rather than treated lower down the waste hierarchy. But given the government's own analysis highlights that these measures will not be enough to achieve the 65 per cent recycling by 2035 target or more ambitious longer term targets, further action will also be needed.⁴³² Individual targets for local authorities, alongside support for transition costs, would drive action by setting an expected level of ambition, as happened in Wales. Before these measures were introduced, Wales and England had similar recycling rates, but Wales' recycling rate is now much higher as set out in box 4.1.⁴³³ Local authority targets could reflect population diversity which may require them to be rolled out at different speeds. For example, elderly users may be more likely to require special collections of medical or sanitary waste, or may have mobility issues or health conditions which mean they require greater local authority support to comply with waste collection requirements. Expanding the government's new ban on single use plastics to a wider range of hard to recycle plastics would also reduce residual waste.⁴³⁴

Box 4.1: What is achievable?

International and domestic examples demonstrate that far higher recycling rates are achievable. The world leader, Germany, recycles 67 per cent of municipal waste. It has achieved this through a range of measures including consistency in twin stream kerbside collections separating out paper and card waste from plastic, metal and composite packaging, with glass waste primarily being taken to special sites.⁴³⁵

Wales introduced standardised collections across local authorities after 2011 alongside other reforms. To ensure local authorities had the capacity to deliver effective recycling collection systems, the Welsh Government provided £68 million in capital support for recycling infrastructure. Additionally, it introduced the possibility of fines for local authorities that missed their recycling targets. In practice, only one local authority has been fined; authorities that missed the targets were usually referred to a support program. The Welsh government also ran communication campaigns to raise awareness of what could be recycled.⁴³⁶ As a result, Wales' recycling rate has increased by around 22 percentage points since 2010 and is now above the government's 65 per cent target for England.⁴³⁷

The current set of government reforms target municipal waste. Commercial and industrial waste represents a significant gap in knowledge.⁴³⁸ Annual government waste statistics do not break down how commercial and industrial waste is treated. As a result, few policies are targeted at this waste stream despite it making up 36 per cent of total waste in England in 2022.⁴³⁹ Although there are similar data gaps for construction and demolition waste, much of this is glass or rubble and a high proportion is reused.⁴⁴⁰ Commercial and industrial waste is likely to include material that will emit greenhouse gases if landfilled.⁴⁴¹ It also contains materials which should be recycled rather than disposed of at lower levels of the waste hierarchy. There will need to be significant reductions in commercial and industrial waste to achieve the government's 2042 and 2050 targets. Government should introduce a measurement system to measure quantities and destinations for this waste stream and take action if needed to deliver its targets.

Recommendation 36: Government should implement its waste collection reforms and materials regulations, to meet the 65 per cent recycling target by 2035, and work towards higher rates of recycling thereafter:

- **without further delay, implement and provide clear guidance on how the collection reforms, known as ‘simpler recycling’, packaging extended producer responsibility scheme and deposit return scheme will work**
- **by 2026, develop individual recycling targets for all local authorities and provide financial support for transitional costs**
- **expand the single use plastics ban to cover a wider range of hard to recycle plastic items**
- **introduce a measurement system, from 2025, on the composition and waste treatment destinations for commercial and industrial waste in England. Where the market is not likely to deliver improved recycling of this waste, government should develop future policies to increase recycling rates further.**

Energy from waste is a major source of waste emissions, second only to landfill.⁴⁴² To hit net zero, as Figure 4.6 indicates, the tonnage of waste treated at energy from waste plants without carbon capture and storage will need to reduce by around a quarter by 2035 and by around 80 per cent by 2050.⁴⁴³ As recycling rates increase, the total volume of waste going to energy from waste, with or without carbon capture, will decrease.⁴⁴⁴

All new plants need to be carbon capture ready to hit net zero, and the Commission’s analysis suggests that there is already sufficient operating capacity in place and in the pipeline to avoid the need for new energy from waste which isn’t carbon capture ready.

In 2022 in England there were 49 energy from waste plants which processed around 13.8 megatonnes of waste.⁴⁴⁵ Allowing for the decommissioning of plants over time and the delivery of new plants already under construction, the operating capacity of plants will remain around ten per cent above available waste to process into the 2050s.⁴⁴⁶

The creation of new energy from waste capacity without carbon capture would be both unnecessary and harmful. The Emissions Trading Scheme, due to cover energy from waste by 2028, will provide a strong incentive to provide carbon capture technology with energy from waste.⁴⁴⁷ In 2030, the Commission estimates that gate fees paid for unabated energy from waste disposal could be up to a third higher than those for plants with carbon capture and storage.⁴⁴⁸ This gap will increase as the Emissions Trading Scheme cap on carbon emissions reduces. However, this will not be enough to guarantee the necessary reduction in tonnage of waste going to energy from waste plants, because local authorities are often locked into long term contracts, some into the 2040s.

Government should send a signal that unabated energy from waste is not a viable option long term and it should take appropriate action to prevent further lock in of emissions from waste incineration. Energy from waste plants can take four to eight years to deliver. There should be a ban on future energy from waste plants which are not already in the local or national planning system, and which do not have plans for carbon capture. This would also ensure that local authorities do not enter into future long term unabated energy from waste plant contracts, avoiding further lock in.

Where possible, residual waste should be avoided. But energy from waste capacity with carbon capture will still be needed, as some vital materials will not be suitable for recycling. Energy from waste is better than disposal to landfill because it generates lower emissions per tonne.⁴⁴⁹ Energy from biogenic waste — waste which emits carbon dioxide — combined with carbon capture and storage can also deliver negative emissions. Government should support the transition of the energy from waste sector to carbon capture and storage through its industrial decarbonisation programme discussed in Chapter 2. Other forms of waste disposal will also need to ensure they adapt their business models to respond to necessary changes in related infrastructure systems. Anaerobic digestion plants, which turn organic waste into biogas, will also need to transition to new markets for their product, such as the industrial heat with carbon capture market, rather than supplying the domestic heat market or burning without carbon capture. As long as these plants adjust to new market conditions, they will remain an important means of treating organic waste.

The Landfill Tax has reduced the volume of waste going to landfill.⁴⁵⁰ Government must increase the Landfill Tax to ensure it remains more expensive than energy from waste, and disposal via landfill remains a last resort. As the tax increases, government should strengthen enforcement of waste disposal obligations to ensure criminals do not illegally dump waste to avoid the increased tax.

Recommendation 37: Government should create stronger incentives for investment in the recycling infrastructure that will be needed in the future, by banning future energy from waste capacity that does not include carbon capture and storage. Government should increase the landfill tax to ensure it remains more expensive than energy from waste. It should also limit demand for existing unabated energy from waste:

- **with immediate effect, local authorities should not sign or renew long term contracts for waste services relying on energy from waste without credible plans for carbon capture and storage⁴⁵¹**
- **local authorities with existing long term contracts should transition away from unabated energy from waste at end of contract, or at break clauses, where possible**
- **government should deliver its commitment to bring energy from waste into the Emissions Trading Scheme in 2028.**

An aerial photograph of a parking lot. At the top, a red-paved area contains several white car icons with charging cables, and a blue car is parked in one of the spaces. Above this area is a yellow-paved section with several blue charging station signs. Below the red area, a grey asphalt road has three white arrows pointing right. Below the road, a large section of the parking lot is covered with solar panels. Several cars are parked in the spaces between the solar panel rows.

5. Investing for the future

The Commission's recommendations require an ambitious programme of policy change. Realising the benefits will require a significant, but manageable, increase in overall investment in economic infrastructure. Public investment will need to be sustained at committed levels of spend beyond 2025. This is aligned with the government's decision to raise the Commission's fiscal remit for public investment in economic infrastructure to 1.1 to 1.3 per cent of GDP per year. And government will need to ensure the UK can attract private sector investment from both domestic and international markets. Delivering this upfront investment will be challenging. But it should lead to lower overall costs for households and businesses in the longer term.

The Commission's analysis suggests that overall investment needs to increase from an average of around £55 billion per year over the last decade (around ten per cent of UK investment) to around £70 to 80 billion per year in the 2030s and £60 to £70 billion per year in the 2040s. This is a significant increase and will be challenging to deliver. But it is what is required to achieve low carbon and resilient infrastructure that supports economic growth and protects the environment.

The costs of the upfront investment will be paid for by consumers over the coming decades, not all at once. There should be support for the households who can least afford extra costs. And in the long run, transitioning to an energy system that runs on cheaper, reliable low carbon electricity should set household costs on an enduring downward trend.

Investing for the future

This Assessment provides a fully costed plan for infrastructure spending that is affordable within the resources set out by government. All recommendations made in this Assessment apply only to areas within UK government competence, and so the plan does not include spending where infrastructure investment decisions rest with the devolved administrations.

The Commission's analysis suggests that overall investment in economic infrastructure will need to increase from an average of around £55 billion over the last decade to around £70 to 80 billion per year in the 2030s and £60 to £70 billion per year in the 2040s. While this is significant, economic infrastructure only accounts for around ten per cent of total investment in the UK economy.⁴⁵² Private capital will be needed to finance the majority of this new investment.

Delaying this investment would mean delaying the benefits of better quality infrastructure services. This Assessment sets out why urgent action is needed to tackle climate change, boost growth and living standards, improve resilience and protect the environment. Delayed action also increases costs. For example, the poor track record on installing energy efficiency has led to higher energy bills in recent years. The UK needs to invest in its own future — and now is the time to act.

For the Commission's recommendations to be deliverable within the funding profiles set out here, the cost of infrastructure must be kept under control. The cost of building some infrastructure in the UK is high by international standards.⁴⁵³ Recent years have seen even more acute pressures from high levels of construction inflation.⁴⁵⁴ The UK must get better

at controlling the costs of major infrastructure projects overall. Part of this should come from improvements in the delivery of infrastructure projects, including the approach to procurement, construction and project management, the use of digital tools, and the capability of government and other infrastructure operators to act as an intelligent client. The Infrastructure and Projects Authority advises government on best practice in infrastructure delivery.⁴⁵⁵ But part of the solution will also come from having greater policy certainty and long term plans, stable funding not feast and famine cycles of investment, removing barriers, and improving infrastructure decision making — all areas covered by this report.

Public investment

The recommendations in this Assessment will require gross public investment from 2025 to 2040 to be at the upper bound of the government's guidance (the Commission's 'fiscal remit') – ie 1.3 per cent of GDP.⁴⁵⁶ From 2040 to 2055, the Commission's recommendations will continue to require substantial spending within the fiscal remit, but there will also be scope for new priorities. More detail on how the Commission's recommendations meet the fiscal remit is set out in Appendix A.

To deliver the Commission's recommendations, the government's planned increase in economic infrastructure investment should be maintained for the long term. Over the last decade, public investment in economic infrastructure averaged around £20 billion. At the latest spending review, government committed to increase this to around £30 billion for the years 2022-23 to 2024-25.⁴⁵⁷ This is a sharp rise, and the government should ensure that it does get spent. Government consistently underspends capital budgets: in recent years one in every six pounds of planned capital expenditure has gone unspent.⁴⁵⁸

In particular, the Commission's recommendations require core public investment for:

- **Transport:** Transport constitutes the largest proportion of government investment in economic infrastructure (Figure 5.1), and will need to be held flat in real terms at an average of almost £28 billion per year between 2025 and 2040, covering:
 - **Urban transport:** Increasing investment from 40 per cent of public investment in transport in 2025 to 50 per cent by 2040, reflecting the economic importance of cities, including a significant increase in investment in public transport in major regional cities, while maintaining London's world class transport system
 - **Roads:** Rebalancing investment across the country, addressing recent underinvestment in the North and the Midlands; the government's last five year plan for investment in the Strategic Road Network only allocated 22 per cent of funding for new investments to these regions⁴⁵⁹
 - **Rail:** The second Assessment has been undertaken on the basis of the delivery of the Integrated Rail Plan. On 4th October, government announced that High Speed 2 from Birmingham to Manchester will not go ahead and set out a new package of transport schemes. This decision leaves a major gap in the UK's rail strategy around which a number of cities have based their economic growth plans. While government has committed to re-allocate all the released funding to improve transport, including rail links, in the North and Midlands, it is not yet clear what the exact scope and delivery schedule is for the proposed new rail schemes.

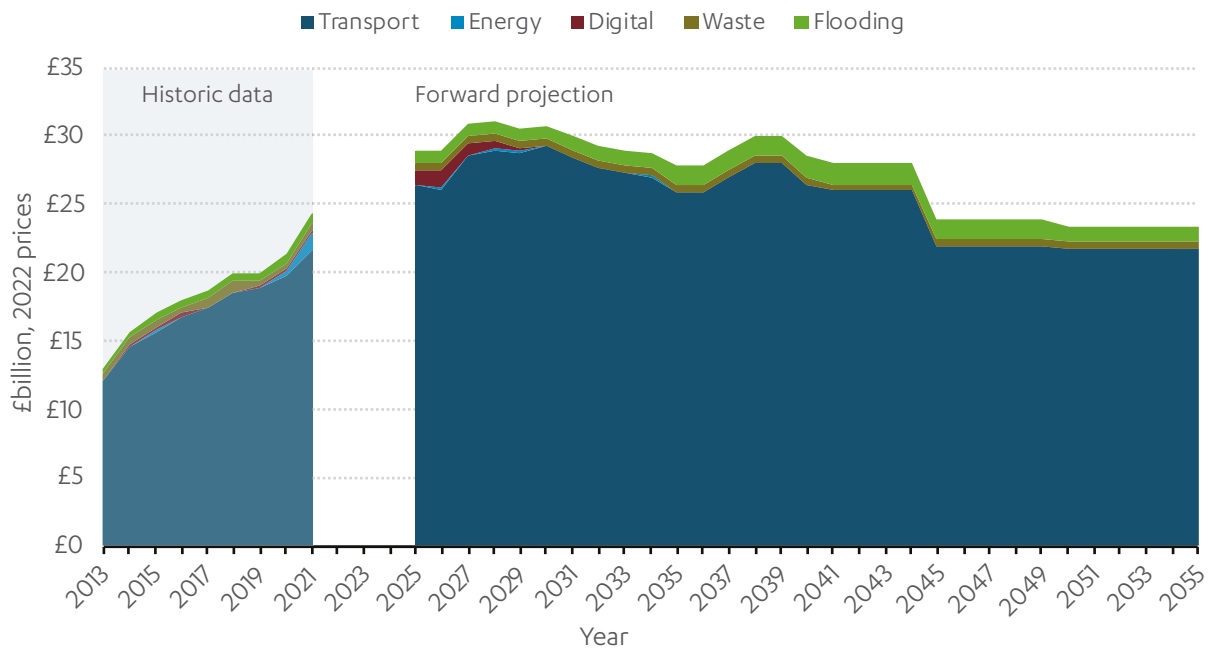
A new comprehensive, long-term and fully costed plan that sets out how rail improvements will address the capacity and connectivity challenges facing city regions in the North and Midlands is needed⁴⁶⁰

- **Energy:** £0.5 to 2.5 billion per year between 2024 and 2050 to decarbonise public sector buildings by deploying heat pumps, heat networks and energy efficiency
- **Digital:** Completing the £5 billion investment on rolling out gigabit capable broadband networks nationwide by 2030
- **Flood risk management:** A rolling programme of around £1 to £1.5 billion per year to protect households and businesses from flooding from rivers and the sea, and to tackle surface water flooding
- **Waste:** Around £0.5 billion per year to safely collect, process and dispose of municipal and industrial waste, preventing harmful waste products from entering the environment.

The Commission has also identified a series of investments that will only be necessary in some future scenarios. These investments are included within an ‘adaptive’ spend line in the fiscal remit. They are fully costed and affordable but should not be committed to until more is known about whether they are required. This includes investment needed if the world warms more than expected, if decarbonising the economy requires more intervention than planned, or if committed infrastructure projects overspend.

Figure 5.1: Public investment in economic infrastructure must be maintained at high levels

Public sector investment in infrastructure, broken down by sector, 2013 to 2055 (excluding capital support to households and businesses)



Source: Commission analysis

Note: Gap in the chart covers the three years of Spending Review 2021. HM Treasury committed £100 billion in current prices over these three years. No sectoral breakdown has been published and the outturn data for this period is not yet available.

In addition to maintaining these high levels of investment in economic infrastructure, government must also spend money to support households through the energy transition. As set out in Chapter 2, the Commission is recommending that all households and small businesses are eligible for a £7,000 subsidy to purchase a heat pump or connect to a heat network, and that lower income households have a full subsidy. To do this, government will need to spend around £3 to 12 billion per year over the next 20 years (around 0.3 to 1.2 per cent of total public spending).⁴⁶¹ Contributing to the capital cost of household heating is an important new role for government, but it is also a temporary one. Once households have transitioned to heat pumps or heat networks, this spending will no longer be required.

Government has directly supported upgrades to housing before. From the 1940s, government started offering subsidies for households to improve their indoor plumbing, including indoor bathrooms. By the 1970s and 80s government was offering grants to cover most of this cost, but the need for government intervention fell away once all houses had been upgraded.⁴⁶²

Figure 5.2: Government should support households to decarbonise their heating systems

Costs of supporting households and small businesses to purchase heat pumps or connect to heat networks

Five year average annual spending (£ billion)	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Government capital spending on supporting households and small businesses to decarbonise heating	2	8	12	4.5	2	0.5

Source: Commission analysis

Attracting private investment

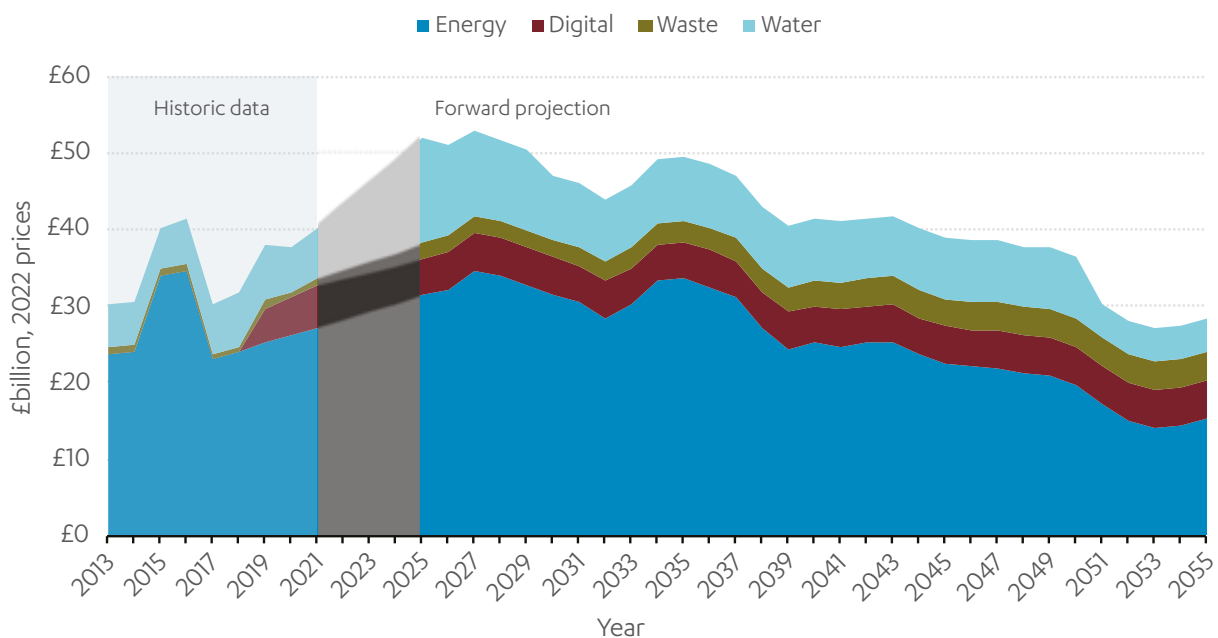
The Commission's analysis suggests investment from the private sector will need to increase from around £30 to 40 billion per year over the last decade to £40 to 50 billion in the 2030s and 40s. The Commission's analysis is based on sector level modelling using publicly available data and expert engagement. It is not based on bottom up assessment of company business plans. The main areas that will require private sector investment are:

- **Energy:** £20 to £35 billion per year between 2025 and 2050 of investment in renewable generation capacity and flexible sources of generation, electricity grids, and hydrogen and carbon capture and storage networks
- **Digital:** £5 billion per year over the next decade in deploying gigabit capable networks nationwide and deploying 5G mobile across the country
- **Water:** Around £12 billion per year from 2025 to 2030 falling to £8 billion per year from 2030 to 2050 to increase water supply, reduce demand, and tackle pollution.

As set out in Chapter 6, securing this increase in private sector investment in economic infrastructure requires stable and coherent policy and regulation, and swifter decision making from government. There is private capital available but market conditions are challenging and there is intense global competition to attract it, with incentives available under the US Inflation Reduction Act and the EU Net Zero Industry Act.⁴⁶³ The UK needs to be competitive in the global market for investment in modern infrastructure. To do so, the UK will need to: have clear, long term policy; remove planning barriers that delay projects and deter investment; and put in place stable regulatory models that allow rates of return that cover cost of capital and are commensurate with the level of risk involved.

Figure 5.3: Delivering a low carbon and secure energy system will require a big increase in private sector investment

Commission estimates of private sector (non household) investment in economic infrastructure, broken down by sector, 2013 to 2055



Source: Commission analysis

Note: The period between the latest outturn data in 2021 and the start of Commission forecasts in 2025 follows a straight line interpolation and is greyed out to reflect the lack of data. Energy investment is typically lumpy and the projection has been smoothed.

While the Commission is calling for significant spending from government to support households to decarbonise their heating, some direct household investment will also be required to purchase heat pumps or connect to heat networks.

For this reason, the Commission is recommending that any spending required from households on heat pumps and heat networks is eligible for zero per cent finance backed by the government.⁴⁶⁴ This means households will be able to spread the upfront cost of a heat pump over several years at no additional cost.

Figure 5.4: Households and small business investment in heat pumps and heat networks

Costs to households and small businesses to purchase heat pumps or connect to heat networks

Five year average annual spending (£ billion)	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Households and small business investment on decarbonising heating	2.1	5.1	10.1	5.3	5.3	7.8

Source: Commission analysis

Note: The numbers in the table represent total investment from households and small businesses to cover the capital costs of installing heat pumps and connecting to heat networks. They do not subtract the costs that households and small businesses would have otherwise spent on gas boilers, which averaged around £6 billion per year between 2015 and 2020. As such, these are not the incremental investment costs households and small businesses will face and are instead the total costs.

The Commission's recommendations are affordable for households

Impact on household costs

The Commission is acutely aware of the context in which it makes the case for increased infrastructure investment. This is particularly important when it comes to the investment required from households and businesses. Since 2019, households, particularly those on lower incomes, have faced a series of adverse shocks, most recently on cost of living. A significant proportion of the population are in fuel poverty.⁴⁶⁵ The costs of the required infrastructure changes will ultimately be funded by households and businesses — either through taxation, bills, or the price of products purchased.

For the next five to ten years, energy costs will largely be driven by the volatile and difficult to predict price of natural gas. But as the economy electrifies, the price of natural gas will become a less significant factor in overall costs.

Over the medium to long term, the key driver of lower household costs will be the move from fossil fuels to cheaper, reliable low carbon electricity. A fossil fuel based system has high operating costs, as natural gas, coal, or oil must be continually purchased and burned to generate power. In comparison, a system running on renewable power, with electrified transport and heat, will have high upfront costs that can be spread over a longer period of time. But once it is built it is cheaper to run. Offshore wind, onshore wind and solar farms have very low operating costs as they require no fuel inputs. Heat pumps and electric vehicles are much more efficient than gas boilers and petrol or diesel cars. The cheaper operating costs of a lower carbon energy system more than offset the high upfront costs of building it, leading to lower household costs over time.⁴⁶⁶

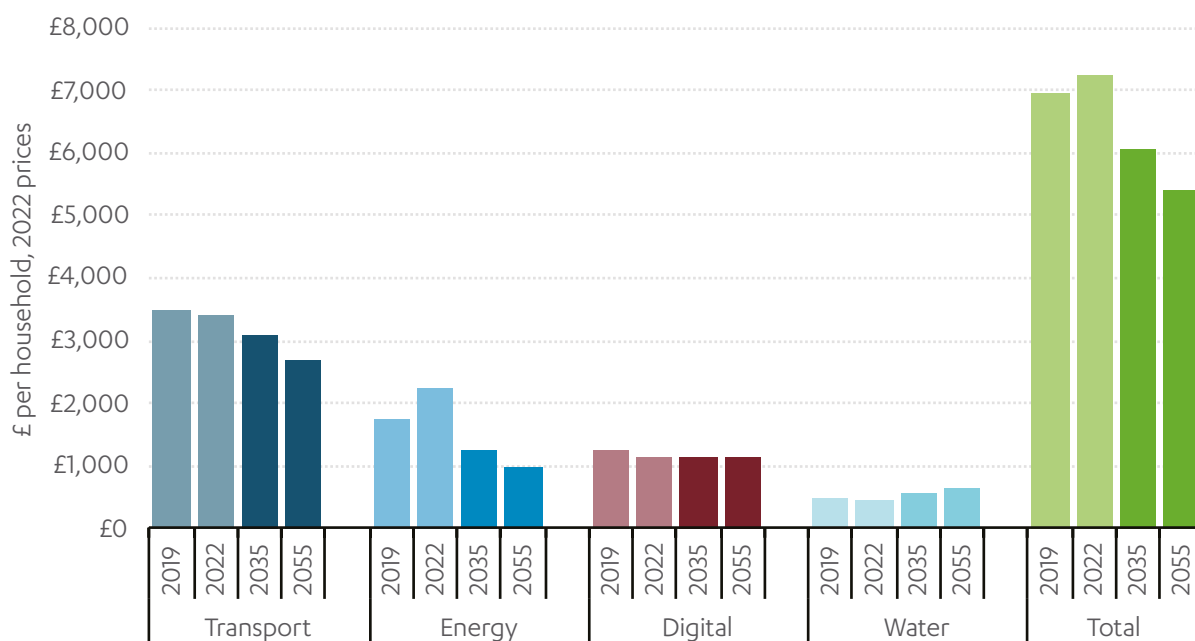
In total, the Commission's analysis estimates that overall household spending on infrastructure services should fall by over £1,000 from today's level of around £7,300 per household to around £5,500-£6,500 by the mid 2030s. The following make up the key elements of household spending on infrastructure services:

- A likely long term rise in water bills to address drought risks and pollution concerns, as set out in Chapter 4 (see Figure 5.5 and Box 5.1).
- This should be more than offset by falling energy spending which the Commission's analysis suggests will reduce from around £2,200 in 2022 to less than £1,400 in the 2030s, below 2019 levels.
- The costs to households of transport should also fall due to the switch to electric vehicles. The average household transport fuel bill is expected to fall from £1,000 to between £500 to 600 in the late 2030s, and the total cost of purchasing an electric vehicle is expected to fall, reaching price parity with a petrol/diesel car by 2030.⁴⁶⁷
- In total, the Commission's analysis estimates that overall household spending on infrastructure services should gradually fall from today's level of £7,300 per household, returning to 2019 level by the mid 2020s and falling to around £5,500 to 6,500 per household by the mid 2030s.

The Commission's analysis on household costs aims to produce an indicative long term projection based on high level modelling, aligned to the recommendations in this Assessment. The Commission has not undertaken a detailed bottom up forecast of household infrastructure costs for the coming years.

Figure 5.5: Overall household spending on infrastructure services should fall by over £1,000 from today's high levels

Household spending on infrastructure services 2019 to 2055



Source: Commission analysis

Distributional impact of the Commission's recommendations

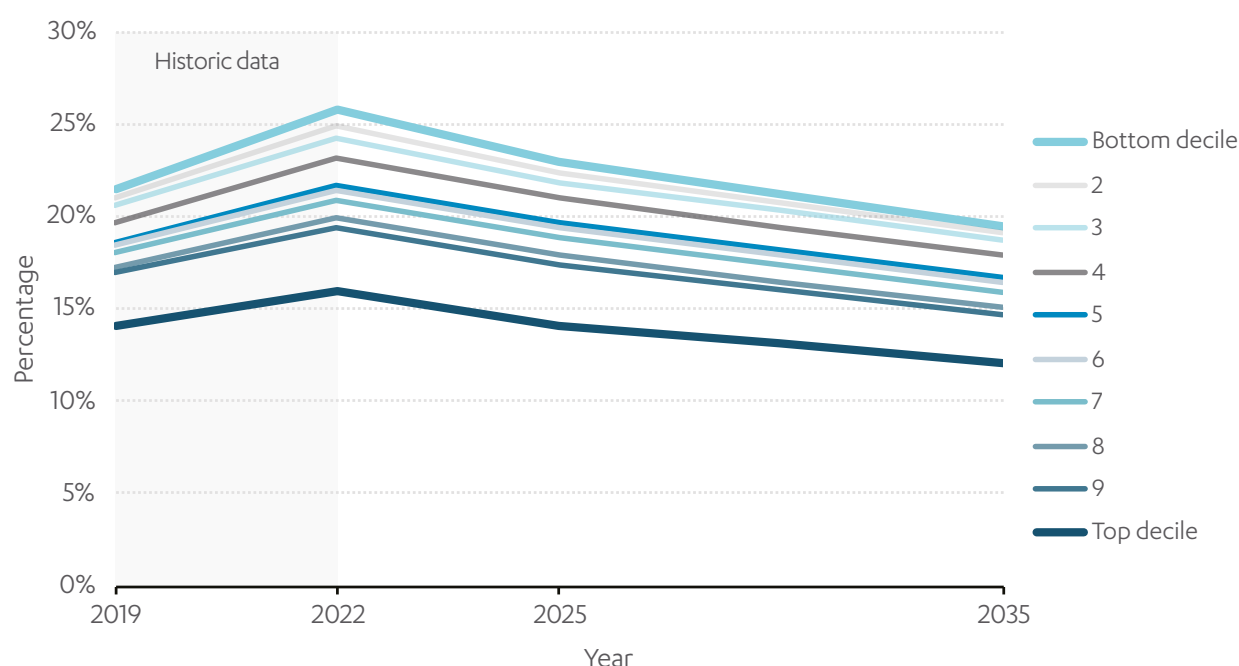
Critically, it is not only the aggregate household spend that is important but also the impact on different types of households.

The Commission's analysis demonstrates that in aggregate, the recommendations in this Assessment should not have a disproportionate impact on households with lower incomes (Figure 5.6).⁴⁶⁸ Households on the highest incomes spend most on infrastructure, so would stand to save more money from falling bills than those on low incomes. But as a proportion of total household expenditure, it is low income households that will likely benefit most. The Commission has recommended supporting lower income households where recommendations would otherwise have a disproportionate impact on them — for example covering the full cost of heat pumps for these households. The key distributional impacts of the Commission's recommendations are:

- lower income households tend to spend a higher proportion of their income on energy and would stand to gain relatively more from falling energy bills and subsidy support for low carbon heating
- higher income households tend to spend a much higher proportion of their income today on transport than poorer groups and will benefit more from falling transport costs
- increasing water bills could disproportionately affect lower income households because there is little variation in water bills across household income groups compared to the variation in income. Government should consider how to best mitigate this impact on lower income households.

Figure 5.6: The Commission's recommendations should not have a disproportionate impact on households with lower incomes

Impact of Commission's recommendations on household spending on infrastructure services by income decile⁴⁶⁹



Source: Commission analysis

More detail on the distributional impacts of the Commission's recommendations across different groups can be found in Appendix A.

People's experience of using and paying for infrastructure services will inevitably differ from aggregate analysis. As argued elsewhere in this Assessment, it will be essential that government remains alert to the financial impacts of implementing the Commission's recommendations on individuals, not just aggregate groups.

In addition to considering the impact of costs on different groups and individuals through distributional analysis, the Commission has also undertaken initial work to consider how the effects of its recommendations might impact on people with different characteristics. This has been done by:

- Undertaking expert external engagement on key equality, diversity and inclusion issues for economic infrastructure sectors. This aimed to understand how people with different characteristics might experience infrastructure, and how policymakers can improve the experience of people with protected characteristics.
- Undertaking social research to understand how people with different protected characteristics experience and view infrastructure, including any barriers that may be faced, in particular in transport, heating and recycling. Key findings from this are covered in Box 1.1 in Chapter 1.

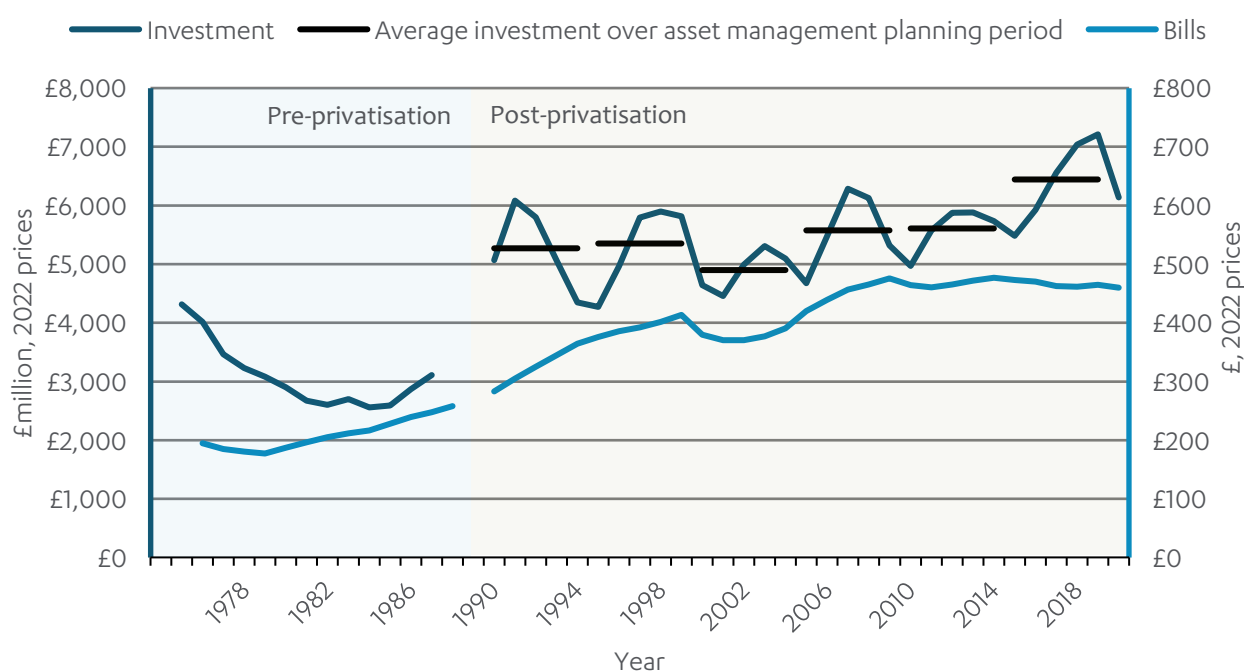
Box 5.1: Investment and bills in the water sector

Having been relatively stable for a number of years, investment in the water sector will need to rise to prepare for a drier future and address environmental concerns. Investment in the water sector rose significantly post privatisation in 1989 (Figure 5.7). To address the infrastructure challenges the water sector faces, as set out in Chapter 4, another step change is now required at a challenging time. Investment needs to rise to around £12 billion per year from 2025 to 2030, and then be maintained at around £8 billion per year from 2030 to 2055 (Figure 5.3).

Water bills will have to rise to pay for this investment. Water bills steadily rose for the first 20 years post privatisation. Since 2010 they have remained broadly flat in real terms at around £450 per household per year (Figure 5.7). The Commission's analysis suggests that rising water bills will disproportionately impact lower income households. As such, government should consider how it can mitigate this negative impact.

Figure 5.7: Investment and bills in the water and wastewater sectors⁴⁷⁰

Capital expenditure and bills in the water industry in England and Wales 1975 – 2021



Source: WaterFacts (1985, 1986, 1988, 1989, 1990), Ofwat (Average Bills Key Dataset), WaterFacts (1985), Cipfa (1988), Ofwat long term data series of company costs (2022)

6. Making good decisions, fast



The Commission's recommendations set out an ambitious programme of change. Realising the benefits will require a significant increase in private sector investment. While there is private finance available, to secure it in a competitive global market, the UK must be able to attract investors based on the strength of its policy and regulatory environment, and the risk adjusted returns available from projects. Government must be able to make good decisions, fast. There need to be changes to planning and regulatory regimes, better strategic policy direction from government, enhanced use of competition within regulated sectors and good infrastructure design. All this can help secure private investment. Changes to public investment decision making frameworks are needed too.

An effective planning system that enables good decisions to be made swiftly is essential for boosting investment and reducing costs. While the Nationally Significant Infrastructure Projects planning regime initially worked well, it has deteriorated in recent years — consenting times have slowed by 65 per cent. Government has taken some positive steps towards reform, but more needs to be done, including: updates to National Policy Statements at least every five years; better use of environmental data; a meaningful and consistent approach to community benefits; integrated spatial planning; and more robust oversight and accountability at the centre of government.

The UK's system of economic regulation needs to be updated to enable the transformational change required to tackle climate change, boost growth and increase resilience. The first step is to ensure the regime retains the confidence of the public and the private sector. To do this, regulators must ensure the private companies they regulate are financially sustainable. Building on this, government must provide guidance to regulators through regular Strategic Policy Statements and regulators should enhance the use of competition within the regulated sectors.

Good infrastructure design provides value for people, places and the climate, while also helping projects finish on time and at lower cost. Embedding design into projects from the outset can improve aesthetics, support community engagement and maximise the benefits of projects. Given the scale and urgency of the required changes to infrastructure, it is essential that design is used to deliver better, faster projects for communities.

Effective policy and decision making are not just needed to support private sector investment, they are needed for public sector investment too. Major infrastructure projects should be given separate budgets for their lifetime. The largest projects should be given their own 'departmental style' settlements with explicit contingency budgets to ensure that cost or time overruns don't prevent other smaller projects from being taken forward. Finally, government should account for maintenance and renewal spending separately from enhancements so that it does not get deprioritised.

The challenge ahead

Securing the wave of private sector infrastructure investment needed requires better policy and decision making. Delivering the recommendations in this Assessment requires £35 to £50 billion of annual private sector investment between 2025 and 2055. Previous investment interest in UK economic infrastructure from both national and international markets suggests there is likely to be private finance available provided infrastructure projects are investable and the returns are appropriate. There is currently intense global competition for private capital with incentives available under the US Inflation Reduction Act and the EU Net Zero Industry Act.⁴⁷¹ The UK needs to be competitive in the global market for investment in modern infrastructure. Securing the necessary level of private investment while keeping the cost of capital down to provide the best value to consumers will require a supportive business environment.

The key conditions include:

- policy stability with clear, long term goals and plans to meet them in all infrastructure sectors — implementing the Commission's recommendations in Chapters 2 to 4 will achieve this
- the removal of delivery barriers that cause delays to projects and increase project financing costs
- a visible and long term pipeline of investment opportunities that will enable the market to invest in skills and operators to build effective contractual relationships with supply chains that keep costs down
- predictable regulatory models that allow rates of return commensurate with the level of risk involved.

Effective policy and decision making are not just needed to support private sector investment, they are needed for public sector investment too. The recommendations set out in this Assessment require an increase of public capital spending from an average of £20 billion per year over the last decade, to £30 billion per year in the coming decades. Public sector spending frameworks must therefore support long term decision making, embed staying power and prevent the regular delays and underspends that have been too common in recent years.

Planning

An effective planning system for large infrastructure projects is essential to rapidly deliver the infrastructure needed to tackle climate change, boost growth and increase climate resilience. For example, more than 17 new nationally significant electricity transmission projects will be required by 2030 to support electrification, a more than fourfold increase on historic rates.⁴⁷² Similarly, at least nine new nationally significant water resource projects will be required before 2030 to prepare for a drier future.⁴⁷³ More broadly, a planning system that embeds the principles of pace, certainty, flexibility and quality decisions is needed to facilitate delivery and increase the levels of private sector investment required over the coming years.

Planning delays increase the costs of infrastructure, which are ultimately passed on to taxpayers for public infrastructure and bill payers for private infrastructure. For large projects, teams can cost around £1.5 million to run per month, and because delays are of uncertain length, it is not

possible to disband and reform teams while they are resolved.⁴⁷⁴ Some types of infrastructure also incur specific costs. In 2022 energy bill payers paid between £600 million and £1 billion in network constraint costs because the existing electricity transmission network did not have the capacity to transmit all of the energy generated by renewables. By 2030 this is estimated to rise to between £1.4 billion and £3 billion per year, unless the capacity of the electricity transmission grid is expanded, as discussed in Chapter 2.⁴⁷⁵

The Nationally Significant Infrastructure Project planning regime was established through the Planning Act 2008 to provide more certainty on the need for nationally significant projects. Initially the system worked well, but since 2012 consenting times have increased by 65 per cent, moving from 2.6 to 4.2 years on average, and the rate of judicial review has spiked in recent years to nearly 60 per cent from a long term average of ten per cent.⁴⁷⁶ The government has recently published the Nationally Significant Infrastructure Projects action plan for reforms to the planning process to update how the regime operates.⁴⁷⁷ The Commission provided government with further advice on how to bring consenting times back to at least 2010 levels in its April 2023 report *Delivering net zero, climate resilience and growth: Improving nationally significant infrastructure planning*.⁴⁷⁸ The key points are summarised below.

Stakeholders support reform of the Nationally Significant Infrastructure Project system rather than its replacement. The Commission's recommendations on planning are designed to ensure the system meets four tests:

- **Faster:** The system must deliver more infrastructure more quickly, at a minimum returning to the two and a half year consenting timetables achieved in the early 2010s. In the longer term, this could be reduced further to around two years due to efficiencies derived from strategic environmental mitigation.⁴⁷⁹
- **More flexible:** The system needs to be able to respond to rapid changes in technology, and to changes in legislation which have implications for planning policy.
- **Increased certainty:** Scheme promoters, investors and communities must have more confidence about the outcome of planning decisions and the time they will take.
- **Better quality:** The system must ensure that environmental outcomes are measurably improved and communities that host nationally important infrastructure receive direct benefits. It must also recognise the importance of good design, as set out in the National Infrastructure Design Principles.⁴⁸⁰

The system has in part become slower because National Policy Statements have not been updated since they were first issued and have not been supported by clear supplementary guidance.

As National Policy Statements have aged there has been less clarity about the need for infrastructure and how this relates to more recent legislation, such as the commitment to net zero. In its action plan the government committed to a first round of updates to National Policy Statements this year. It should go further by making it a legal requirement to review key National Policy Statements for energy, national networks and water resources at least every five years. Government should also set out the criteria for when the other National Policy Statements should be reviewed. Statements should explicitly refer to sector specific spatial plans, such as the new spatial plan for energy transmission, the Roads Investment Strategy

and Water Resource Management Plans. This would give better guidance to stakeholders and the Planning Inspectorate regarding the alignment of the need case for infrastructure, system configuration and design with national priorities and environmental management.

Recommendation 38: By 2025, government should introduce legislation to make at least five yearly reviews of the National Policy Statements for Energy, Water Resources and National Networks a legal requirement. These statements should include clear tests, refer to spatial plans and set out clear timelines and standards for consultation during the pre-application stage. Reviews should consider the appropriateness of existing and future technologies and thresholds. Government should amend legislation to bring onshore wind into the Nationally Significant Infrastructure Project system as soon as possible. By 2025, government should also set out the criteria for triggering reviews of other National Policy Statements.

Government should make the system more flexible, enabling National Policy Statements to keep pace with legislative change, such as the net zero target. ‘Modules’ should be produced and attached to legislation to set out how these changes relate to existing statements. These modules should not need to be separately consulted on as the legislation will go through, or be scrutinised by, Parliament. This will increase certainty in the system by ensuring statements align with newer legislation and enabling departments to set out how they do so.

Recommendation 39: By July 2024, government should introduce a system of modular updates to National Policy Statements linked to primary or secondary legislation to ensure clarity on how future legislative change relates to National Policy Statements.

Currently, the environmental impact of infrastructure is managed on a project by project basis. This undermines the speed, quality and certainty of the system. The system is slowed down because individual projects are often required to collect up to three years of environmental data, sometimes duplicating recently gathered data. The system has fewer optimal outcomes because environmental management is considered on a project by project basis, but environmental impacts should be managed at ecosystem level. Finally, the system is less certain because the lack of clear guidance and expectations can mean that projects’ proposed environmental management plans are open to legal challenge.

Better management of the environmental impact of infrastructure will require the sharing of baseline data and the development of a library of mitigations, which will take a while to deliver time savings. For prioritised infrastructure, government should take a proactive approach to measuring environmental impacts by gathering baseline data and agreeing mitigations with developers. This should start with wind generation and electricity transmission, followed by water resource infrastructure, because these sectors are critical for delivering net zero, energy security and climate resilience.

Recommendation 40: By the end of 2024, the Department for Environment, Food and Rural Affairs should introduce a data sharing platform for environmental data with clear data standards, sharing relevant developer and local nature recovery strategy

data. By the end of 2025 statutory consultees should develop a library of historic and natural environmental mitigations for different kinds of infrastructure. Statutory consultees should also receive and use new resource to gather baseline data and agree strategic mitigations for urgent infrastructure, firstly for wind generation and electricity transmission, and then water resources, by the end of 2025.

Some projects, such as electricity transmission lines, deliver benefits at the national level, but not always at a local level. Providing social, economic or environmental benefits at local as well as national level could improve community trust in the system which could in turn reduce the risk of legal challenge. Requiring developers to engage with communities early to understand their needs also improves the quality of the system. Community benefits have tended to be allocated on a voluntary basis by industry and developers and, as such, the level of funding and how it has been allocated has varied. Given the scale and rate of infrastructure change required, government should set out a national framework for compulsory community benefit which provides a menu of options, while retaining the flexibility for local communities to indicate which benefits they prefer. This will introduce the measures necessary to ensure local communities receive consistent, tangible and fair benefits from hosting network infrastructure that supports national objectives. To align planning with economic regulation, these benefits should be funded through regulatory settlements such as price reviews or by being added to costs agreed at capacity auctions.

Recommendation 41: By the end of 2023, government should develop a framework of direct benefits for local communities and individuals where they are hosting types of nationally significant infrastructure which deliver few local benefits.

The failure to update National Policy Statements suggests that some departments may have overlooked planning in favour of short term concerns. More projects are also requiring multiple extensions at the decision stage. All parts of the system, including ministerial decision making, must be more disciplined to meet timeframes, and must resolve issues at the appropriate stage in the process. Given the challenges faced by Nationally Significant Infrastructure Projects, stronger accountability is needed at the centre of government to guarantee the system meets the tests the Commission has proposed in recommendation 38. This could be in the form of a new appropriately skilled unit or task force under the Prime Minister or Chancellor to closely monitor the performance of the system, coordinate regular and consistent reviews of National Policy Statements, and to learn lessons from applications, unblocking systemic issues affecting certain types of schemes as they emerge.

Recommendation 42: By the end of 2023, a central coordination and oversight mechanism should be developed, reporting to the Prime Minister or the Chancellor, with measurable targets for reducing consenting times for Nationally Significant Infrastructure Projects.

Statutory consultees have a clear remit, such as protecting the natural environment or the historic environment, but this is not always aligned to the consenting and delivery of nationally significant infrastructure. Updates to National Policy Statements should provide statutory

consultees with clear guidance on balancing different considerations. But the need for national infrastructure should also be reflected in the resourcing and incentives for these bodies. Similarly, developers should be required to demonstrate effective engagement and agreement with statutory consultees in advance of projects being accepted for examination, in the form of service level agreements.

Recommendation 43: By May 2024, performance indicators for statutory consultees operating under a cost recovery model should form part of compulsory service level agreements with developers, with budget implications for failure to meet agreed service levels. Developers' applications should only be accepted for examination once a service level agreement is in place.

Box 6.1: Planning for the electricity transmission network

As set out in the Electricity Networks Commissioner report, the Independent System Operator should develop and regularly update a strategic spatial energy plan, including for the transmission network.⁴⁸¹ This should build on recent positive steps in strategic planning.⁴⁸² The strategic spatial energy plan should connect government policy and energy network plans. This should be developed with oversight from Ofgem, who would then allow the investment through the regulatory process. Critically, the strategic spatial energy plan should be linked to regular updates of the National Policy Statements so that location of infrastructure, as well as type and need, is established.⁴⁸³

Regulation

While it is important that the UK maintains its system of independent economic regulation, it should be urgently reformed. This is needed to retain investor confidence, improve outcomes for consumers and enable the transformational change required to tackle energy security, climate change and climate resilience.

The UK's regulatory system was designed over thirty years ago and was world leading. With privatised utilities, regulation was developed to allow monopolies to be operated effectively by the private sector without adverse impacts on consumers.⁴⁸⁴ While significant new investment was needed, the utilities were expected to stay more or less the same; only incremental changes were expected to be required.⁴⁸⁵ The role of regulation was meant to address problems of major and unavoidable monopoly power, such as the access to and pricing of monopoly network services, and the limited scope for competition.⁴⁸⁶ Overall investment rose sharply in the 1980s and 90s but has plateaued in the 2010s.⁴⁸⁷

However, in some instances, the system has not been effective. From unacceptable levels of water pollution and leakage to slow electricity grid connections, key outcomes in these sectors are falling short of what is needed. This is partly because the regulatory system has not fully internalised key externalities such as greenhouse gas emissions or pollution. It is no

longer appropriate for investment to function on a ‘just in time’ basis as envisaged in current regulatory models. To keep pace with the rapid action needed to reach net zero and build climate resilience, investment ahead of need is essential. The challenge is to find the right balance between investment incentives by allowing long term appropriate rates of return based on whole life costs, while also ensuring that consumers do not pay more in bills than is necessary to make infrastructure networks fit for purpose.

It is important that the regime retains the confidence of both the public and the private sector. As a prerequisite for this, regulators must ensure that the private companies they regulate are financially sustainable — their approach should include stress testing of financial capability. This includes considering appropriate ratios related to gearing and performance related risk adjusted returns. Greater consistency should also be created across price regulated regimes, including how the allowed cost of capital is set. The recent guidance published by the UK Regulators Network is a positive step towards achieving this greater consistency.⁴⁸⁸

For the regulatory system to support policy objectives, strategic direction from government is needed through regular Strategic Policy Statements for each sector. At a time when the water and energy sectors need transformational change, rather than marginal efficiency improvements, regular Strategic Policy Statements provide clarity on the need to prioritise investment, especially when it is required ahead of need. These statements should set out a coherent long term vision for sectors, aligned with government’s policy priorities.

The Statement of Strategic Priorities given to Ofcom in 2019 has helped secure alignment between government and regulator on the goal of nationwide gigabit capable broadband networks, and the network competition model and investment incentives to achieve it. This stability, alongside Ofcom’s long term regulatory settlement that allows pricing flexibility for fibre services while protecting consumers, has helped create market confidence and contributed to the significant increases in private sector investment and rapid delivery.⁴⁸⁹ Gigabit capable broadband connections have increased to around 75 per cent of the country, up from 5 per cent in 2018.⁴⁹⁰

Box 6.2: Ofgem and net zero duty

In its 2019 report on infrastructure regulation, the Commission recommended government introduce legislation to ensure regulators’ duties require them to consider the government’s commitment to net zero greenhouse gas emissions by 2050 in their decisions.⁴⁹¹ This would encourage long term investment in low carbon infrastructure and improve climate resilience.⁴⁹²

In June 2023 government confirmed plans to amend the Energy Security Bill to give Ofgem a new net zero duty, delivering on the Commission’s recommendation.⁴⁹³

Competition can play a greater role in the energy and water sectors. Investment aimed at addressing strategic challenges will be made in the context of high levels of uncertainty and rapid technological change which fundamentally changes infrastructure design. Enhanced use of competition for strategic enhancements has a role to play here — the evidence is clear

that in general more competitive markets are more innovative and productive.⁴⁹⁴ Removing some major strategic investments from price controls and opening them to competition could both boost innovation and give investors the confidence to deliver long term projects within a stable regulatory environment. However, the Commission recognises that competition is not appropriate in all circumstances. In some cases, introducing competition could slow delivery in the short term or hinder the coordinated delivery of networks. It will be important that government and regulators collaborate to identify the right times to introduce competition.⁴⁹⁵

Box 6.3: Models for introducing more competition in the water sector

Ofwat is introducing more competition “for the market” through its Direct Procurement for Customers model. This involves a water or wastewater company competitively tendering for services in relation to the delivery of certain large infrastructure projects. Ofwat believes this will result in water companies competitively procuring more aspects of an infrastructure project, including financing for the project. This should deliver innovation and resilience by allowing new participants to bring fresh ideas to the delivery of key projects and lower whole life costs.

The Thames Tideway Tunnel project used a similar model under the Specified Infrastructure Projects Regulations 2013, where the provider is directly licensed by Ofwat. This model has the potential to provide improved value for money over the Direct Procurement for Customers model by securing a lower cost of capital.⁴⁹⁶

Recommendation 44: Government must empower regulators to facilitate investment in a strategic way that address the long term challenges of net zero, energy security and climate resilience by:

- **setting out a long term strategic vision for each of the regulated sectors, through strategic policy statements, updated during each Parliament**
- **requiring regulators to enhance the role of competition by introducing legislation to remove any barriers to the use of competition and focusing ‘standard’ periodic price controls on the maintenance of existing networks and using tendering processes for strategic enhancements, with a clear, public justification required where tendering is not used.**

In addition to changes to the regulatory regime, government must urgently establish business models to secure private capital to invest in new energy infrastructure. Government should focus support on those technologies that are critical to national energy needs or where the UK has a comparative advantage. New business models are needed to support deployment of hydrogen and carbon capture and storage networks, and new forms of flexible electricity generation. Government must also ensure that the Contracts for Difference mechanism for renewable energy is designed so that it attracts investment in the future as it has in the past. These business models must provide investors with clarity and certainty, alongside an appropriate rate of return. The Commission’s recommendations on new energy infrastructure are set out in Chapter 2.

Box 6.4: The UK Infrastructure Bank

In the first National Infrastructure Assessment, the Commission recommended that government establish a new operationally independent infrastructure finance institution, designed around three key building blocks — sound banking, additionality, and economic and social impact.⁴⁹⁷ Its role would be to help address ongoing market failures around innovation in the infrastructure sector and provide additional policy stability.⁴⁹⁸

The UK Infrastructure Bank was established in June 2021 and put on a statutory footing in March 2023.⁴⁹⁹ The Bank has £12 billion of initial capital to deploy and can issue up to £10 billion of guarantees.⁵⁰⁰ It has two strategic objectives — to help tackle climate change and support regional and local economic growth.⁵⁰¹ In delivering these strategic objectives the UK Infrastructure Bank also aims to ‘crowd in’ private capital and make a positive financial return.⁵⁰² In June 2022, the UK Infrastructure Bank published its first strategic plan.⁵⁰³ By March 2023 it had already agreed 20 deals for projects in telecoms, energy, water and transport.⁵⁰⁴

Transformative design

In all sectors, the number of infrastructure projects will increase. Each project will provide opportunities to use good design processes and collaborative working to deliver multiple environmental and community benefits across the country. And the increased number of projects means there will be opportunities to link and integrate infrastructure in creative ways that maximise return on investment.

Good infrastructure design is about more than aesthetics. Design is as much about process as it is about product, and structured design thinking should be embedded from the outset of all projects. This can drive collaboration, solve problems, reduce risk, enhance the environment, support genuine community engagement — and deliver multiple benefits.⁵⁰⁵

In the first Assessment, the Commission recommended that all nationally significant projects should appoint design champions to their boards.⁵⁰⁶ Champions would be responsible for advocating for design at the highest level. The first Assessment also called for the use of the Commission’s design principles — climate, people, places and value — which provide a framework for all infrastructure projects.⁵⁰⁷ These recommendations were accepted by government.

There is now some emerging evidence that the Commission’s design principles have started to be used effectively.⁵⁰⁸ But there needs to be a step change to deliver the appointment of board level design champions, coupled with action to embed wider design leadership on all nationally significant projects.

The Institution of Civil Engineers is working to further define and develop the scope of the design champion role, and the experience and qualifications required. Preliminary findings from their recent research shows broad support for the role, with interviewees suggesting it should become a legal requirement and sit at board level in an advisory capacity.⁵⁰⁹ Champions should help set the right brief, support the development of a vision and bespoke design principles for each project, and ensure that these inform board level decision making. Getting

design champions appointed at board level will be a positive step. But given the scale of transformation required across economic infrastructure, the infrastructure sectors will need creative, collaborative leaders at all levels. Leaders should:

- embed a design culture from the very earliest stages, including when setting a project's brief and its desired outcomes
- deliver cultural and organisational change, where necessary, so that design is understood as a process that will drive the project
- ensure the right design disciplines are brought onto a project at the right time, recognising the different skills required throughout its lifecycle
- identify multiple beneficial outcomes, based on a sound understanding of place, community, environment and economic context, going further than simply providing operationally efficient infrastructure
- ensure project specific design principles, once developed, underpin the governance of design through the project lifecycle
- develop a structured design process that facilitates meaningful local consultation, provides a framework for early consideration of environmental issues, and 'de-risks' projects.

No one knows a place like the people who live there. Leaders must recognise the vital importance of early, effective and sustained engagement with all relevant local communities. Effective engagement can streamline projects by addressing issues and community ambition early, limiting local concerns and increasing public buy in. With public support comes a smoother and quicker planning process. And effective community engagement, resulting in locally tailored approaches, can deliver infrastructure projects with wider beneficial outcomes.

Box 6.5: Place plans

'Place plans' offer communities the opportunity to develop proposals for developments and land use in their area. But they can also help communities understand their aspirations and ambitions for how infrastructure can deliver future change.⁵¹⁰ Emerging evidence suggests that place plans have been used successfully in Wales and Scotland, enabling better delivery of national strategic policy objectives at a local level. They can also improve trust between communities and local government, creating a more open dialogue to inform the provision of future public services.⁵¹¹

There may be opportunities for further place planning, and the delivery of multiple, beneficial outcomes, alongside any increased use of strategic, spatial planning across infrastructure sectors. And as the number of infrastructure projects increases over the coming years, this may provide opportunities to draw several projects into a single community impact area to allow for aggregated outcomes via a place plan.

The Commission's design principles were deliberately high level, so that they were applicable across all economic infrastructure sectors. But project specific principles, once developed, should provide a common understanding of a project's ambition, and the role that design will

play in delivering it. There is value in producing ‘how to’ guidance, to explain the process that should be followed in developing project specific principles. The Design Group will work with a wide range of stakeholders across the public and private sectors to produce this guidance, setting out how design leaders can develop project specific principles and apply them throughout a project’s life cycle. The guidance will draw on best practice and relevant case studies, and will apply to public and private sector projects.

Recommendation 45: The Design Group will develop further guidance that explains how design leaders, using an effective, structured process, should develop and embed project specific design principles. By 2024, the Infrastructure and Projects Authority should incorporate this guidance within its assurance review regime and expect all Nationally Significant Infrastructure Projects to follow it.

Skills and supply chains

The proposals set out in this Assessment will not be delivered without an adequate skills base in the UK. Developing this pool of skilled labour will likely require active intervention from government. The UK will also need to improve access to supply chains to meet the large and, in some cases, urgent need for infrastructure. From the Environment Agency’s floods programme, major enhancements to wastewater and water networks, and significant upgrades to electricity grids, to installing low carbon heating in buildings, the availability of adequate skills and effective supply chains will be critical enablers.

Several studies have considered the labour and skills requirements for different sectors.⁵¹² It is, for example, estimated that between 135,000 and 725,000 net new jobs could be required in low carbon sectors by 2030.⁵¹³ There is a very real risk that skills shortages and lack of supply chain capacity will deter some investments, push up the costs and delay the delivery of infrastructure projects. The problem with the UK’s engineering skills base has been well reported for many years.⁵¹⁴ Other skills shortages such as in planning and environmental assessment may also become a constraint on infrastructure deployment. The global supply chain for key infrastructure components, such as specialised high voltage grid equipment, is already stretched, as many countries and companies are seeking to invest at the same time.⁵¹⁵ Operators need to establish long term relationships with key suppliers.

Long term policy certainty is a prerequisite for building effective skills and supply chains. While the Commission has not considered infrastructure sectors’ specific skill and supply chain requirements in this Assessment, it is clearly beneficial for the market to have visibility on a pipeline of investable projects around which it can plan, invest in skills and develop long term relationships with suppliers. These demand signals in sectors such as energy, water and transport are, in turn, dependent on government setting long term goals and strategic plans — and then sticking to them. The package of recommendations the Commission has developed, if implemented, would help to provide this long term certainty.

Public spending frameworks

Central government must make funding decisions for the long term. Too often funding decisions are short term, leading to stop start and underinvestment in maintenance and renewal. Government investment is around six times as volatile as its day to day spending.⁵¹⁶ The UK government often fails to deliver on its planned capital spend, with one in every six pounds of planned spending going unspent.⁵¹⁷ The UK is an outlier in this regard, with public investment more volatile than in most comparable countries.⁵¹⁸ Delivering major projects requires a clear and evidence based assessment of costs and risks at the outset, strong project management and delivery skills, and a sensible approach to budget management.⁵¹⁹

Government has made some positive progress by setting budgets for most major infrastructure for at least five years. These include:

- the strategic road network through the Road Investment Strategy programme
- the rail network through the Control Periods
- support for local transport through the City Region Sustainable Transport Settlements
- flood resilience through the Flood and Coastal Erosion Risk Management Capital Investment Programme
- support for gigabit broadband in uncommercial areas through Project Gigabit.

Government should build on this by setting fixed budgets for the life of major infrastructure projects. These budgets should allow flexibility for money to be moved forward and backwards across years. This would help remove the illusion that delay saves costs. In reality, delay is more likely to increase costs and it always delays benefits.⁵²⁰

The biggest infrastructure megaprojects should be given their own ‘project expenditure limit’ separate from the department in which they sit. Megaprojects are long term commitments that extend well beyond Spending Review periods. The evidence is clear that megaprojects are extremely hard to deliver to cost and on time.⁵²¹ Giving these projects their own separate expenditure limit will mean that cost or time overruns do not have a knock on impact on all the other projects a department is running. But to be effective such an expenditure limit would need to have explicit contingency budgets built in. Effective governance would be required to ensure these budgets are not used for gold plating. The set up and management of the contingency in the Public Sector Funding Package for the London 2012 Olympic Games is an example of how effective this process can be.⁵²²

Setting budgets for the lifetime of large scale projects requires effective upfront scrutiny of costs before business cases are signed off. It is essential that government has the right skills to effectively interrogate the cost of proposed projects, not just assess the potential benefits. Greater use of historical evidence on cost and time overruns for similar projects — for example, by using reference class forecasts— is essential. And embedding adaptive and modular approaches should be encouraged for better risk management.

In addition to separate budgets, maintenance and renewal spend for economic infrastructure should be accounted for separately within public spending frameworks. Maintenance and renewals are necessary to protect the current asset stock. Delaying this, as is often done,⁵²³

pushes costs into the future and leads to more asset degradation. A separate category of spend would force government to systematically assess the costs of maintaining the economic infrastructure capital stock and plan this in through five yearly budgets. Periodic reviews of the asset base would need to be conducted to decide whether a certain asset should be retired, with departments identifying a longer term pipeline that highlights assets with significant renewal cost such as the Thames Barrier.

Finally, government should provide longer term certainty over infrastructure funding by adopting the funding profile the Commission has set out in its fiscal remit (Figure A.3). This would provide longer term certainty and allow more effective planning of future projects. More detail on the Commission's recommended funding profile is set out in Annex A.

Recommendation 46: By 2025, government should reform public spending frameworks for infrastructure to provide longer term certainty and more effective management by:

- **setting fixed budgets for capital infrastructure for at least five years**
- **moving away from annual controls for major capital projects and instead giving major projects a fixed budget with the ability to move money forward and backward across years within that budget**
- **accounting for maintenance and renewal spend separately from capital or resource spend — these budgets should be set for at least five years, with departments identifying an indicative longer term pipeline that highlights any particularly large upcoming maintenance or renewal spend**
- **giving infrastructure 'megaprojects' their own 'project expenditure limit' including explicit contingency budgets, separate to the department which runs them**
- **adopting the funding profile set out by the Commission's recommendations in future spending reviews.**

Appendices

A. Fiscal and economic remit

The recommendations in this Assessment set out a fully costed plan for economic infrastructure over the next 30 years. The recommendations are affordable within the guidelines for public investment in economic infrastructure set out by government. This appendix provides a detailed breakdown of the costs of the recommendations to households, businesses, and government, and the public investment required to realise them.

Background

The costs of economic infrastructure services are all ultimately paid for by households. Businesses pass their infrastructure costs on to households, either through bills or the cost of products purchased. The money government invests in economic infrastructure comes from households, via general taxation. For clarity, in this appendix costs are presented according to who pays them first: households, businesses, or government.

The Commission has fully costed all the recommendations set out in this Assessment. To fulfil the requirements of the Chancellor's remit letter to the Commission, these costs are presented in two different categories: the 'economic remit' and the 'fiscal remit'.

The economic and fiscal remits align with UK government competence, respecting devolved responsibilities for economic infrastructure. They do not include spending where infrastructure investment decisions rest with the devolved administrations in Scotland, Wales and Northern Ireland.

The economic and fiscal remits cover costs of the six economic infrastructure sectors: energy, transport, water and wastewater, waste, flood risk management and digital communications.

The economic remit

The Commission has analysed how the recommendations in this Assessment will impact costs for households, businesses, and government from 2025 to 2055. These are covered in the Commission's 'economic remit'. The economic remit does not include the gross public investment required to realise the Commission's recommendations — this is included instead in the 'fiscal remit' in the next section. The economic remit does, however, include any resource (day to day) expenditure required by government on economic infrastructure.

There are high levels of uncertainty associated with creating projections of costs 30 years into the future. To account for this, costs are presented as ranges rather than simple point estimates. The Commission's analysis is based on sector level modelling using publicly available data and expert engagement. It is not based on bottom up assessment of company business plans. The

Commission has produced an indicative long term projection based on high level modelling, aligned to the recommendations in this Assessment. The Commission has not undertaken a detailed bottom up forecast of household infrastructure costs for the coming years.

In total, the Commission's analysis estimates that spending on infrastructure services by an average household should fall from today's level of around £7,300 per household, to between £5,500 to £6,600 by the mid 2030s, and £5,100 to £6,100 by 2055. The detailed sectoral breakdown of these costs is set out in Figure A.1. The key factors behind this are:

- Household spending on energy will fall from around £2,200 in 2022 to below £1,400 in the 2030s and remain at this lower level until 2055. This is due to a renewable based electricity system reducing the electricity price, more efficient heat pumps becoming the main way homes are heated and government support for households through the transition (see fiscal remit). More detail on the Commission's energy recommendations is set out in Chapter 2.
- Household spending on transport should also fall due to the switch to electric vehicles. The average household transport fuel bill is expected to fall from around £1,000 in 2022 to between £500 to £800 in the 2030s and £300 to £350 in 2055. There are two key variables that create this cost reduction: electricity will likely be cheaper than petrol and diesel and electric vehicles are more efficient than conventional cars and vans.
- Household spending on digital infrastructure, both broadband and mobile, is expected to stay broadly flat in real terms. The Commission is assuming that declines in the unit cost of data will be offset by increased demand, as over the last decade.⁵²⁴
- Water bills will likely increase by around £90 - £130 by 2030, and a further £20 - £170 by 2055. An increase in investment is needed over the next 30 years in the water sector to address drought risks and pollution concerns. This will be recovered through higher household bills. This challenge is discussed in more detail in Chapter 4.

Figure A.1: Infrastructure related spending by an average household should fall over time

Costs per household (£ per household in 2022 prices)

Source of costs	2022	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Transport							
Fuel costs	1,060	800-980	650-790	480-590	390-470	320-390	290-360
Rail and bus fare	450	400-490	400-490	420-500	430-520	440-520	430-520
Other operational costs	1,400	1,260-1,540	1,260-1,540	1,260-1,540	1,260-1,540	1,260-1,540	1,260-1,540
Vehicle purchases	590	550-620	530-650	530-650	530-650	530-650	530-650
Total	3,500	3,010-3,630	2,840-3,470	2,690-3,280	2,610-3,180	2,550-3,100	2,510-3,070
Energy							
Electricity bill	1,000	420-570	340-430	310-380	280-350	230-280	200-240
Heating bill	950	630-890	510-650	460-560	410-500	380-470	370-450
Heat capital costs	290	270-330	270-330	400-490	410-500	300-370	380-470
Total	2,240	1,320-1,790	1,120-1,410	1,170-1,430	1,100-1,350	910-1,120	950-1,160
Water							
Water bill	440	490 - 520	540 - 590	560 - 620	590 - 660	590 - 710	550 - 740
Digital Communications							
Broadband bill	500	450-550	450-550	450-550	450-550	450-550	450-550
Mobile bill	440	400-490	400-490	400-490	400-490	400-490	400-490
Capital expenditure	200	190-210	190-210	190-210	190-210	190-210	190-210
Total	1,140	1,040-1,250	1,040-1,250	1,040-1,250	1,040-1,250	1,040-1,250	1,040-1,250
All sectors							
Total	7,320	5,890-7,170	5,600-6,730	5,500-6,560	5,350-6,380	5,100-6,070	5,100-6,080
Of which are bills	3,330	2,140-2,500	1,950-2,120	1,810-1,980	1,730-1,890	1,650-1,790	1,610-1,730

Source: Commission analysis

The Commission has undertaken similar analysis of how the aggregate costs to households, businesses and government of economic infrastructure services may evolve over the next 30 years. The scope of these costs differs from the costs per household above in three ways:

- the costs are calculated in the aggregate, so population growth means that the total amount spent is increasing, even though the per household cost is falling
- taxes, such as VAT or fuel duty, are removed from the calculation to better reflect the costs required to build, maintain and access infrastructure
- the aggregate cost includes all costs to businesses, and government resource expenditure on economic infrastructure, examples of which include: support for renewable electricity generation through Contracts for Difference; subsidies for rural bus services; and the Commission's recommendation for government to provide zero per cent financing to households and small businesses to install a heat pump.

These aggregate costs for households, businesses and government experience similar trends as in per household costs, although these are less clear in some cases due to population growth. The detailed sector breakdown is presented in Figure A.2.

Figure A.2: The economic remit

Aggregate costs to households, business and government (£ million 2022 prices)

Category	Source of costs	2022	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Transport								
Households	Fuel and operating costs	58,400	50,300-61,400	50,700-62,000	50,400-61,700	50,100-61,300	49,200-60,200	48,900-59,800
	Rail and bus fare	10,700	10,000-12,200	10,300-12,600	10,900-13,200	11,400-13,800	11,900-14,400	12,200-14,700
	Vehicle purchases	13,900	13,500-15,300	13,300-16,300	13,700-16,700	13,900-17,000	14,000-17,100	14,100-17,200
	Total	83,100	73,700-88,900	74,400-90,900	75,000-91,600	75,400-92,100	75,200-91,700	75,200-91,700
Business and industry	Fuel and operating costs	51,000	44,300-54,100	45,000-55,000	45,000-55,000	44,300-54,100	43,300-52,900	43,100-52,600
	Rail and bus fare	3,100	2,800-3,500	2,900-3,600	3,000-3,700	3,100-3,800	3,200-3,900	3,300-4,000
	Vehicle purchases	30,300	29,300-33,300	29,000-35,500	29,800-36,400	30,200-36,900	30,400-37,200	30,600-37,400
	Total	84,300	76,500-90,900	77,000-94,100	77,800-95,100	77,600-94,800	76,900-94,000	76,900-94,000
Government	Resource expenditure	14,100	12,700-15,500	12,700-15,500	12,800-15,600	12,900-15,800	13,100-15,900	13,200-16,000
Total		181,500	162,900-195,300	164,000-200,500	165,700-202,400	166,000-202,600	165,200-201,600	165,300-201,700

Category	Source of costs	2022	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Energy								
Households	Energy bills	51,500	27,700-38,800	23,100-29,300	21,500-26,300	19,500-23,900	17,700-21,600	16,800-20,500
	Heat capital and maintenance	5,700	5,400-6,600	5,600-6,800	8,500-10,300	8,800-10,800	6,600-8,100	8,700-10,700
	Total	57,200	33,100-45,400	28,700-36,100	30,000-36,600	28,400-34,700	24,300-29,700	25,500-31,200
Business and industry	Energy bills	37,800	26,400-34,600	25,700-31,500	28,100-34,300	29,400-35,900	29,000-35,500	27,900-34,100
	Heat capital and maintenance	2,100	1,200-1,500	1,000-1,300	1,000-1,200	800-1,000	900-1,000	800-1,000
	Total	39,900	27,600-36,100	26,800-32,800	29,100-35,500	30,200-36,900	29,900-36,500	28,700-35,000
Government	Energy bills	2,500	1,700-2,300	1,600-2,000	1,800-2,200	1,900-2,300	1,800-2,200	1,800-2,100
	Resource spend on policy	20,800	10,600-13,000	10,200-12,500	3,600-4,400	1,200-1,400	800-900	600-700
	Total	23,300	12,400-15,300	11,900-14,500	5,300-6,500	3,000-3,700	2,600-3,200	2,300-2,800
Total		120,300	73,100-96,700	67,300-83,400	64,400-78,700	61,600-75,300	56,800-69,400	56,500-69,000
Water								
Households	Water bill	2,400	2,800-2,900	3,200-3,300	3,400-3,600	3,600-4,000	3,700-4,400	3,400-4,700
Business and industry	Water bill	200	280-290	320-330	340-360	360-400	370-440	340-470
Government	Water bill	13,800	16,000-16,800	17,900-19,400	19,200-21,300	20,500-23,100	21,000-24,800	19,600-26,400
Total		13,800	16,000-16,800	17,900-19,400	19,200-21,300	20,500-23,100	21,000-24,800	19,600-26,400
Digital communications								
Households	Fixed and mobile bills	22,500	20,900-25,600	21,600-26,400	22,100-27,100	22,500-27,500	22,600-27,700	22,700-27,800
	Digital capex	4,700	4,600-5,000	4,800-5,200	4,900-5,300	5,000-5,400	5,000-5,400	5,000-5,500
	Total	27,200	25,600-30,600	26,300-31,500	27,000-32,400	27,400-32,900	27,600-33,100	27,800-33,300
Business and industry	Fixed and mobile bills	4,100	3,800-4,600	3,400-4,600	3,000-4,600	2,700-4,600	2,400-4,600	2,200-4,600
Government	Resource spend on policy	0	10					
Total		31,300	29,400-35,200	29,800-36,100	30,100-36,900	30,200-37,400	30,100-37,700	29,900-37,800
Waste								
Business and industry		7,600	10,600-12,300	10,900-12,700	8,000-9,900	8,300-10,300	8,700-10,700	9,100-11,200
Government		3,400	4,200-4,500	4,200-4,300	3,700-3,800	3,300-3,500	3,300-3,500	3,300-3,500
Total		11,000	14,800-16,800	15,100-17,100	11,700-13,700	11,600-13,700	12,000-14,200	12,400-14,700
All sectors								
Total		358,000	296,600-360,400	294,900-355,700	292,100-352,000	291,200-350,900	287,000-345,800	287,300-346,400

Source: Commission analysis

The fiscal remit

The Commission's remit also asks it to separately set out the implications of its recommendations on public investment (the 'fiscal remit'). Specifically, the remit asks the Commission to consider gross public investment in economic infrastructure (often referred to as government capital expenditure). The figures presented here are therefore not adjusted for losses in the value of economic infrastructure due to depreciation.

The cap on the fiscal remit is set at two levels: 1.1 and 1.3 per cent of GDP each year. The total amount of gross public investment in economic infrastructure that would be required to deliver the Commission's recommendations must fall within these limits. To make sure the spending is deliverable, the Commission is asked to ensure that the fiscal remit does not vary by more than 0.1 per cent of GDP year on year.

All of the six sectors the Commission covers are within scope of the fiscal remit. This includes spending that is traditionally considered investment in infrastructure, like building new roads and expanding the fibre broadband network. It also includes any capital grants to households and businesses that support their access to infrastructure. The Commission's recommended subsidies for heat pumps, heat networks and energy efficiency are therefore included.

The recommendations in this Assessment meet the requirements of the fiscal remit. The Commission's recommendations will see infrastructure spend rise to, and stay at, 1.3 per cent of GDP for the 15 years from 2025 to 2039 (Figure A.3). From 2040 to 2055, recommendations will continue to require substantial spending within the fiscal remit, but there will also be scope for new priorities. The fiscal remit table below collates the major commitments from government and the Commission's recommendations in this Assessment.

Alongside investment in each sector, the Commission recommends that funding for specific but uncertain future events be held to enable government to adapt future investment plans without reopening existing commitments. In the fiscal remit the Commission has included an investment line for 'uncertainty and adaptive pathways'. This investment is sufficient to cover: potential outcomes from the Commission's recommended assessment of specific telecommunications needs of the energy, water and transport sectors; the potential need for further investment to adapt transport and flooding infrastructure for a changing climate; acceleration of the decarbonisation of road transport; and major enhancements to London's public transport, should the city see significant growth in commuters over the next 30 years. This line also includes some contingency for the Integrated Rail Plan and successor schemes.

While many future infrastructure needs can be foreseen and explicitly included in the fiscal remit, it is also likely that new priorities will emerge over the coming 30 years. The Commission's recommended investment package therefore includes an element of 'unallocated spend' in later years. This is set at a level sufficient to keep public investment in economic infrastructure at around 1.1 per cent of GDP per year.

Figure A.3: The fiscal remit

Gross public investment in economic infrastructure (fiscal remit) under the Commission's recommendations, average annual expenditure £ million 2022 prices

Source of cost	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Transport						
<i>Interurban transport</i>						
Road enhancements	2,900	2,800	2,800	0	0	0
Road renewals	1,500	1,700	1,700	0	0	0
Rail enhancements	1,800	1,700	1,700	0	0	0
Rail renewals	4,000	4,400	4,400	0	0	0
Strategic transport	0	0	0	11,100	11,100	11,100
Integrated Rail Plan and successor schemes	6,100	4,300	3,300	1,900	0	0
<i>Local and urban transport</i>						
Local authorities devolved budgets	8,000	8,000	8,000	8,000	8,000	8,000
Local roads backlog	600	600	0	0	0	0
London	2,500	3,400	3,100	2,900	2,600	2,600
Urban major projects	50	700	1,700	2,000	0	0
<i>Decarbonisation</i>						
Additional decarbonisation measures	400	400	300	300	300	0
Total	27,800	27,900	27,000	26,100	22,000	21,700
Energy						
NIC's greenhouse gas removals recommendation	30	20	10	0	0	0
Decarbonisation and energy efficiency	3,400	8,000	12,100	4,600	2,100	400
Total	3,500	8,100	12,200	4,600	2,100	400
Digital communications						
Digital programmes	800	10	0	0	0	0
Total	800	10	0	0	0	0
Waste						
Local authority waste expenditure	500	500	500	500	500	500
Total	500	500	500	500	500	500
Flood risk management						
Flood risk protection	800	1,000	1,400	1,400	1,400	1,100
NIC's surface water flooding recommendation	40	40	40	40	40	40
Total	900	1,000	1,400	1,500	1,500	1,200
Cross sector						
Uncertainty and adaptive pathways	2,200	1,800	1,100	1,000	4,400	7,400
Unallocated spending for future investment priorities	0	0	0	7,900	11,400	14,000
All sectors						
Total	35,600	39,300	42,200	41,500	41,900	45,200
As a per cent of GDP	1.3%	1.3%	1.3%	1.2%	1.1%	1.1%

Source: Commission analysis

Notes on the table: 1) individual spend lines may not sum to total due to rounding; 2) Commission recommendations to increase spend on climate adaptation are captured through additional money for 'renewals' (on the assumption that adapting the existing asset base is best done as part of a routine renewals schedule); 3) 'Strategic Transport' captures the sum of all interurban rail and road transport spend from 2040 onwards, reflecting uncertainty over the required split between modes; 4) The Commission's estimates for the costs of IRP include HS2 phases 2a, 2b and East in 2022 prices. On 4th Oct govt announced these phases would not go ahead and instead the money would be allocated to other transport projects including rail. Pending full costings for the specific alternative plans, the Commission has retained the cost of phases 2a, 2b and East in the fiscal remit; 5) recommendations to expand the City Region Sustainable Transport Settlements are captured within local devolved budgets; 6) 'Urban major projects' aligns with the recommendation for public transport projects initially starting in Manchester, Leeds, Birmingham and Bristol; 7) within energy, 'Decarbonisation and energy efficiency' captures the full value of capital support to all types of household as they decarbonise and the direct costs of switching public buildings to electric heating.

The Commission's remit also asks it to set out how its recommendations could be prioritised at the lower bound of the fiscal remit of 1.1 per cent of GDP per year. Figure A.4 fulfils this requirement.

While the Commission is not recommending that gross public investment in economic infrastructure be within 1.1 per cent of GDP, the following key changes would be required to achieve this:

- Reducing the total value of government support to households for decarbonising heating and energy efficiency from £150 billion over the 30 years to £100 billion over the 30 years. This remaining £100 billion could be spent in various ways. For example, it could be used to support those in social housing and on lower incomes through the energy transition. Alternatively, it could focus on providing support for the rest of the population as they switch to electric heating. However, unlike the package of recommendations the Commission is proposing, there would not be enough funding available both to fully cover the cost for lower income households and provide material support to the rest of the population.
- Reducing the money available for road and rail enhancements by around 20 per cent, compared to the Commission's recommendations. Road enhancements would receive £500 to £600 million less per year from 2025-34 compared to the recommended package. Around £300 to £400m less per year would be spent on rail enhancements from 2025-39.
- Reducing the increase in local authority devolved budgets by 20 per cent (equivalent to £1.5 billion per year) from 2025-29, then raising it from 2030-34 until it reaches the recommended level in 2035. However, within this overall reduction, the Commission recommends maintaining the full value of City Regional Transport Settlements and the spending for mass transit projects, given the opportunity for growth.

To meet the Sixth Carbon Budget and the 2050 net zero target, this lower level of funding for energy from government would mean greater costs fall directly on households and small businesses. This would increase the risk of not delivering switches to low carbon heating at the pace needed.

To continue to provide an incentive to switch and therefore reduce the risk of emissions targets not being met, non subsidy based policy mechanisms would need to do much more. Under a scenario where government support is reduced to £100 billion:

- policy to rebalance gas and electricity prices would need to go further, and the price of gas would need to be kept higher than would otherwise be the case

- additional costs would be imposed on government through provision of zero per cent financing for the upfront cost of heat pumps above the lower subsidy level
- government's proposed clean heat market mechanism would need to roughly double the price of a gas boiler by the early 2030s, if no subsidy was provided for switching to a heat pump.⁵²⁵

Taking these actions could reduce the risk of meeting the Sixth Carbon Budget, but that is not guaranteed. This approach would rely heavily on the clean heat market mechanism which has not yet been implemented. This package would also place additional costs on consumers. Pushing up the price of gas, the price of gas boilers and placing the additional upfront cost burden of a heat pump on to consumers could add an extra £350 per year to the average household energy cost in the late 2020s and 30s, compared to the policy package recommended by the Commission. The cost to government of offering zero per cent finance would also increase by around 40 per cent, or £5 billion, as households require larger loans to cover the higher cost of heat pumps.

Figure A.4: Limiting public investment to 1.1 per cent of GDP would require key changes

Gross public investment in economic infrastructure (fiscal remit) when limited to 1.1 per cent of GDP, average annual expenditure (£ million 2022 prices)

Source of cost	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Transport						
<i>Interurban transport</i>						
Road enhancements	2,300	2,300	2,800	0	0	0
Road renewals	1,500	1,700	1,700	0	0	0
Rail enhancements	1,400	1,400	1,400	0	0	0
Rail renewals	4,000	4,400	4,400	0	0	0
Strategic transport	0	0	0	11,100	11,100	11,100
Integrated Rail Plan and successor schemes	6,100	4,300	3,300	1,900	0	0
<i>Local and urban transport</i>						
Local authorities devolved budgets	6,800	7,300	8,000	8,000	8,000	8,000
Local roads backlog	600	600	0	0	0	0
London	2,500	3,400	3,100	2,900	2,600	2,600
Urban major projects	50	700	1,700	2,000	0	0
<i>Decarbonisation</i>						
Additional decarbonisation measures	70	70	500	500	500	0
Total	25,300	25,900	26,700	26,600	22,200	21,700
Energy						
NIC's greenhouse gas removals recommendation	30	20	10	0	0	0
Decarbonisation and energy efficiency	2,400	5,500	7,800	3,300	1,600	300
Total	2,500	5,600	7,800	3,300	1,600	300

Digital communications						
Digital programmes	800	10	0	0	0	0
Total	800	10	0	0	0	0
Source of cost	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Waste						
Local authority waste expenditure	500	500	500	500	500	500
Total	500	500	500	500	500	500
Flood risk management						
Flood risk protection	800	1,000	1,400	1,400	1,400	1,100
NIC's surface water flooding recommendation	40	40	40	40	40	40
Total	900	1,000	1,400	1,500	1,500	1,200
Cross sector						
Uncertainty and adaptive pathways	90	100	30	2,100	4,400	7,400
Unallocated spending for future investment priorities	0	0	0	4,800	11,400	14,000
All sectors						
Total	30,900	33,100	36,500	38,700	41,600	45,100
As a per cent of GDP	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%

Source: Commission analysis

Notes on the table: 1) individual spend lines may not sum to total due to rounding; 2) Commission recommendations to increase spend on climate adaptation are captured through additional money for 'renewals' (on the assumption that adapting the existing asset base is best done as part of a routine renewals schedule); 3) 'Strategic transport' captures the sum of all interurban rail and road transport spend from 2040 onwards, reflecting uncertainty over the required split between modes; 4) Urban major projects aligns with the recommendation for public transport projects initially starting in Manchester, Leeds, Birmingham and Bristol; 5) recommendations to expand the City Region Sustainable Transport Settlements are captured within local devolved budgets; 6) within energy, 'Decarbonisation and energy efficiency' captures the full value of capital support to all types of household as they decarbonise and the direct costs of switching public buildings to electric heating.

Figure A.5: Household energy costs if would need to be £300 per year more expensive in the late 2020s and 2030s than under the Commission's recommended interventions

Household energy costs if gross public investment is limited to 1.1 per cent of GDP per year

Source of costs	2022	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Electricity bill	1,000	420-570	340-430	310-380	280-350	230-280	200-240
Heating bill	950	880-1,170	700-860	580-710	450-550	390-480	370-450
Heat capital & maintenance	290	310-380	370-450	530-640	500-610	320-390	390-470
Total	2,240	1,610-2,120	1,410-1,740	1,420-1,730	1,230-1,510	940-1,150	960-1,160
Compared to the Commission's recommendations at 1.3 per cent of GDP per year	0	Increase of 290-330	Increase of 290-330	Increase of 250-300	Increase of 130-160	Increase of 30	Increase of 0-10

Source: Commission analysis

Distributional analysis

The cost to households of infrastructure services can be significant. Alongside its activities to ensure compliance with the Public Sector Equalities Duty, the Commission has undertaken distributional analysis of the recommendations in this Assessment to better understand their impact on households. The median UK household income is around £32,000, so the £6,000 median (£7,000 mean) household spend on infrastructure services is a large portion of expenditure. The Commission has conducted distributional analysis for a range of protected characteristics and vulnerable groups, looking at: income, region, urban/rural, ethnicity, gender, marital status, disability and age.

The analysis presented here is based on household data from the Office for National Statistics' Living Costs and Food Survey. For each group explored by the analysis, average spending on infrastructure is presented as a percentage of today's total household expenditure. Changes in infrastructure costs are applied in line with the Commission's analysis of household spending in the economic remit (see Figure A.2 above) but total household expenditure is kept constant, to avoid making assumptions about future changes in the distribution of wealth. As such, any future wage growth is not taken into account, and so the Commission's analysis may overstate the proportion of household spend going to infrastructure assets and services in the future. This analysis uses total household expenditure, rather than direct measures of household income, reflecting the Commission's desire to look at household living standards at all life stages. Direct measures of income may fail to capture the resources available to some households, notably students and retirees, or may be skewed by temporary changes in household income due to unemployment or one off windfalls.⁵²⁶

The Commission's analysis demonstrates that, in aggregate, the recommendations in this Assessment should not have a disproportionate impact on households with lower income (Figure A.6). Households on the highest incomes spend most on infrastructure, so stand to save more money from falling bills than those on low incomes. But as a proportion of total household expenditure, all household groups benefit roughly equally. The Commission has recommended supporting lower income households where recommendations would otherwise have a disproportionate impact on them — for example, covering the full cost of heat pumps for these households. The key dynamics of the distributional impacts of the Commission's recommendations are:

- lower income households tend to spend a higher proportion of their income on energy and stand to gain relatively more from falling energy bills and subsidy support for low carbon heating
- higher income households tend to spend a much higher proportion of their income today on transport than poorer groups and will benefit more from falling transport costs
- increasing water bills due to increasing investments will disproportionately affect lower income households — government should consider how to best mitigate this impact on lower income households.

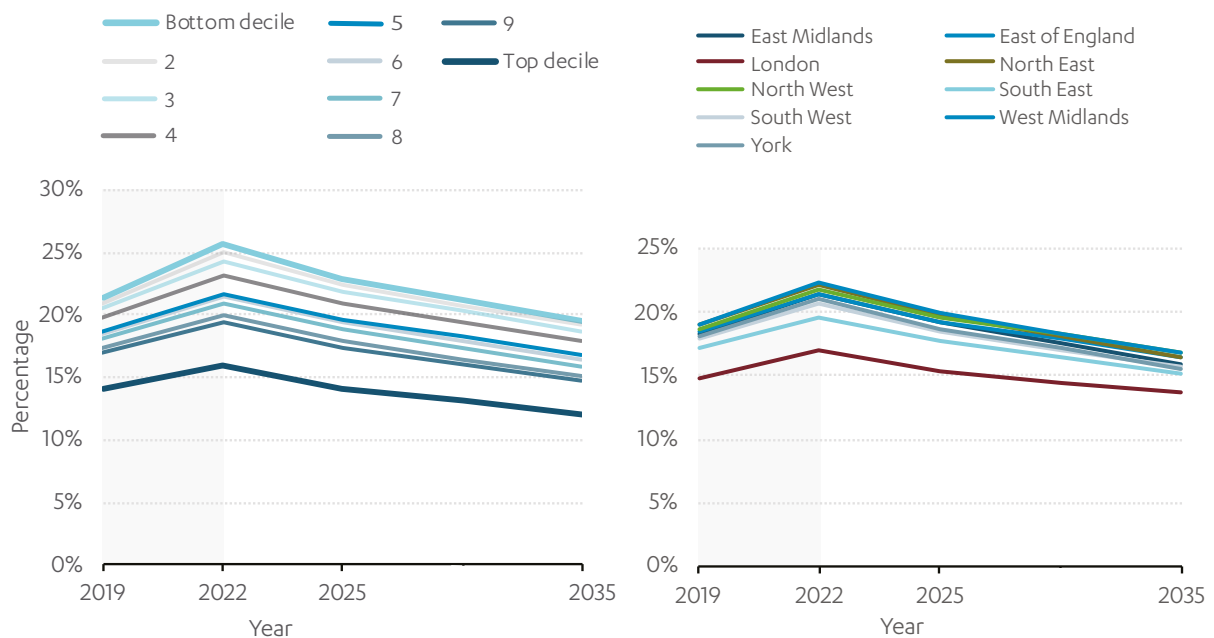
The Commission's analysis suggests that all households would benefit roughly equally from the steadily declining costs of infrastructure services (Figures A.6-A.13). Declining costs would be experienced by households in all income groups and all regions of the country, by those in both rural and urban areas, by households with different gender, ethnic and marital characteristics, by young families and retirees, and by households with and without disabled members.

Figure A.6 (left): Households on the lowest incomes will continue to spend the highest proportion of their incomes on infrastructure, but all groups will spend less overall

Percentage of household spend on infrastructure services by expenditure decile

Figure A.7 (right): Households in southern England will continue to spend a lower proportion of their income on infrastructure compared to the rest of the country, but disparities will reduce slightly

Percentage of household spend on infrastructure services by region



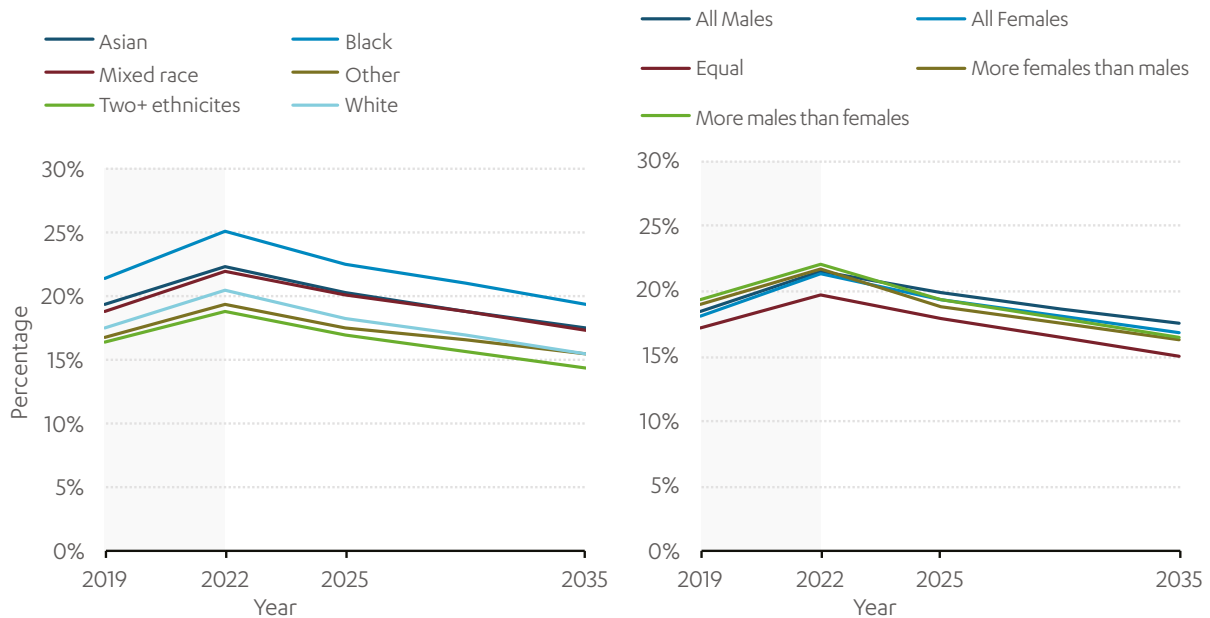
Source: Commission analysis

Figure A.8 (left): Black households will continue to spend a higher proportion of their incomes on infrastructure than other groups

Percentage of household spend on infrastructure services by ethnicity

Figure A.9 (right): Households with equal numbers of men and women will continue to spend the lowest proportion of their incomes on infrastructure

Percentage of household spend on infrastructure services by gender



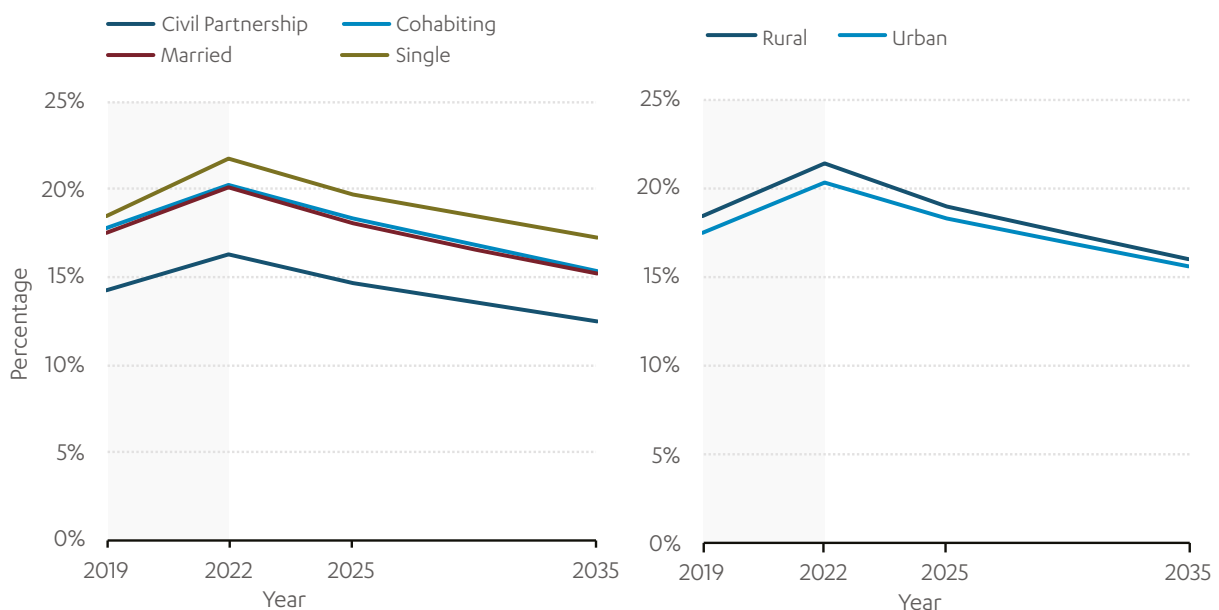
Source: Commission analysis

Figure A.10 (left): Single households will continue to spend a higher proportion of their incomes on infrastructure than other groups

Percentage of household spend on infrastructure services by marital status

Figure A.11 (right): There will be little change in differences in spending on infrastructure between households in urban and rural areas over time

Percentage of household spend on infrastructure services by household location



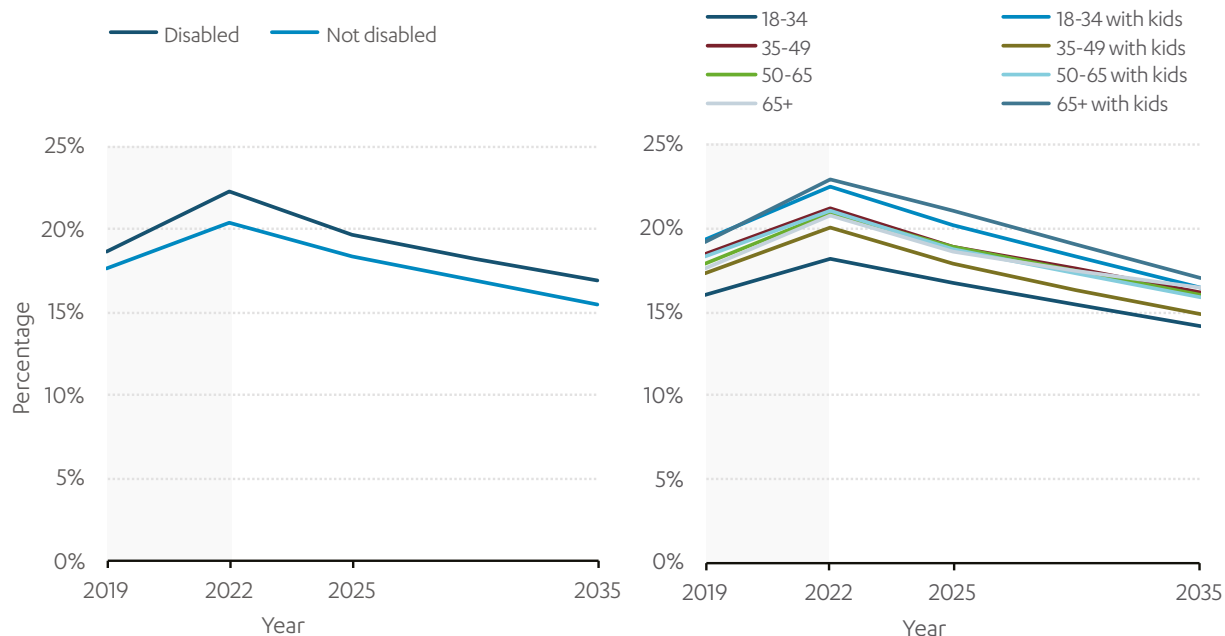
Source: Commission analysis

Figure A.12 (left): There will be little change in differences in spending on infrastructure by people with and without disabilities over time

Percentage of household spend on infrastructure services by disability status

Figure A.13 (right): Spending on infrastructure by households with children will fall faster than for households without children

Percentage of household spend on infrastructure services by age and presence of children



Source: Commission analysis

B. List of recommendations

Energy and reaching net zero

1. Government should target a total of 60GW of short duration flexibility by 2035. Government should introduce policy in 2024 to enable this, ensuring all viable technologies have a route to market.
2. Government should by 2024 have in place a business model to support hydrogen fired generation and ensure that by 2030 multiple large scale power stations are deployed for both gas generation with carbon capture and storage and hydrogen fired generation. By 2035, deployment of low carbon gas generation should be sufficiently scaled to provide 30TWh of persistent flexible generation to manage the potential for prolonged shortfalls during winter.
3. Government should target establishing a minimum of eight TWh of large scale hydrogen storage to be in operation by 2035.
4. Government should phase out unabated gas fired generation so that it generates less than two per cent of electricity by 2035, and prevent unabated gas power stations from operating in the wholesale, balancing and capacity markets by 2040 at the latest. Actions to deliver this should include:
 - ensuring that carbon capture and storage enabled and hydrogen fired electricity generation stations deploy ahead of unabated gas power stations, through a combination of carbon pricing and emissions limits on new and existing unabated gas power stations
 - shortening the length of future capacity market contracts for unabated gas power stations from the 2025 auction round, ensuring that these contracts do not extend beyond 2040
 - allowing the Independent System Operator to turn on unabated gas power stations ‘in extremis’ to ensure security of supply.
5. Government should reform governance arrangements to enable the transformational change in network infrastructure that will be required to support a decarbonised electricity system, including:
 - completing the setup of the Independent System Operator by the end of 2024, and ensuring it has the duties, tools and access to data necessary to plan and manage interactions between energy vectors
 - ensuring the Independent System Operator has a duty to develop and maintain a strategic spatial energy plan, with the first version of this plan in place by 2025 and updated regularly
 - providing strategic clarity to Ofgem through the Strategy and Policy Statement by the end of 2023 on the need for investment in electricity distribution and local flexibility solutions ahead of need that are sufficient to meet the demands of electric vehicles and heat pumps implied by carbon budgets
 - establishing the Regional System Planners proposed by Ofgem in time to inform the next electricity distribution price control in 2028.
6. Government should develop a strategic energy reserve to support resilience to economic shocks. To deliver this, legislation should be introduced to give the Secretary of State

powers to establish and control the reserve. Government should take the necessary actions to develop a reserve that can be used to generate 25TWh of electricity in 2040, and then maintain it at this level.

7. Government should reduce energy demand from buildings by:
 - extending the Social Housing Decarbonisation Fund to deliver £5.1 billion of capital spending on energy efficiency improvements between 2024 and 2030 and devolve directly to local authorities to deliver the programme
 - continuing the obligation on energy companies to install energy efficiency improvements in households on lower incomes, delivering £8.8 billion of capital spending between 2024 and 2035
 - providing zero per cent financing for households and small businesses for the cost of energy efficiency installations
 - setting out, by the end of 2025, a plan to tighten and enforce minimum standards in the private rented sector.
8. Government must commit long term funding to deliver low carbon heat across the public sector estate, social housing and for households on lower incomes by:
 - allocating £28.9 billion between 2024 and 2050 to deliver low carbon heat and energy efficiency improvements in the public sector estate, including across devolved administrations, and 75 per cent of this funding should be committed to 2035
 - allocating £33.8 billion between 2024 and 2050 to deliver low carbon heat in the social housing sector, and devolve funding to deliver the programme, and 35 per cent of this funding should be committed to 2035
 - allocating £41.7 billion between 2024 and 2050 to deliver low carbon heat to all other households on lower incomes, and 35 per cent of this funding should be committed to 2035.
9. To support seven million buildings in England to switch from fossil fuel heating to a heat pump or heat network by 2035, government should incentivise building owners, including private landlords by:
 - providing a subsidy of £7,000 per property owner for installing a heat pump or connecting to a heat network from 2024, with information published on how this subsidy will reduce over time as take up increases and installation costs fall
 - providing zero per cent financing for the upfront costs above the subsidy
 - taking policy costs off electricity bills and ensuring the cost of running a heat pump is lower than the cost of running a fossil fuel boiler
 - making the process of installing a heat pump or low carbon heat network as fast and simple as possible.
10. Government should not support the rollout of hydrogen heating. Infrastructure solely for hydrogen heating should not be eligible for support under the hydrogen transport business model and today's gas users should not be expected to pay for the conversion of natural gas infrastructure to transport hydrogen through existing price controls.
11. Government should plan for the end of the use of natural gas for heat by:
 - banning new connections to the gas network from 2025
 - regulating, by 2025, to end the use of fossil fuel heating in commercial buildings over 1,000m² by 2035

- ending the sale of all new fossil fuel boilers in 2035
 - making provisions for the process of disconnecting customers and decommissioning, or repurposing, the gas network
 - establishing a mechanism for local democratic input into decommissioning plans
 - working with Ofgem and the Health and Safety Executive on a plan to ensure the switch is safe and efficient and that consumers in vulnerable circumstances are protected.
12. Government must accelerate deployment of electric vehicle public charge points to reach its expectation of 300,000 public charge points by 2030 and keep pace with sales of electric vehicles.
 13. Government should, by 2025, establish a monitoring and review regime for its transport decarbonisation plans that reflects the uncertainty in carbon emissions outcomes from surface transport. The need for action to ensure decarbonisation targets are met should be reviewed annually, and all relevant information made publicly available. Carefully designed, adaptive policies that can be introduced, if necessary, should be prepared as part of the work on the integrated transport strategy.
 14. Government should ensure policy actively encourages industrial decarbonisation at the speed needed to hit its carbon budgets through a mix of carbon pricing, other incentives, regulation and shifting public procurement to low carbon products.
 15. Government should commit to the development of a carbon transmission pipeline and storage network that can transport and store at least 50MtCO₂e per year by 2035. The actions needed to deliver this are:
 - Set out a vision for an initial core network by the end of 2024, including clear identification of the key sites and routes. Based on current evidence, the Commission proposes the key sites for the core network should be Grangemouth and North East Scotland, Teesside, Humberside, Merseyside, the Peak District and Southampton.
 - Support development expenditure costs for front end engineering design studies to bring projects in the core network to the point where they could apply for development consent.
 - Establish a process beyond the existing allocation rounds (track one and two) for awarding regulatory asset base contracts for the build and operation of the core network. There should be the option of awarding business model contracts to pipeline and storage projects separately.
 - Designate a system operator with a duty to efficiently manage the network and ensure network codes and governance arrangements are established in a manner fit for this purpose.
 - Set out how decisions will be taken to add additional pipeline routes or stores to the core network, including timings and the decision making criteria for awarding development expenditure in the shorter term and business model contracts at a later date.
 16. Government should commit to the development of a core hydrogen pipeline network that is operating no later than 2035. The actions needed to deliver this are:
 - Set out a vision for an initial core network by the end of 2024, including clear identification of the key sites and routes. Based on current evidence, the Commission proposes the key sites for the core network should be Grangemouth and North East Scotland, Teesside, Humberside, Merseyside and South Wales.

- Support development expenditure costs for front end engineering design studies to bring projects in the core network to the point where they could apply for development consent.
- Expedite delivery of the planned business model for hydrogen pipeline networks which must include clarity on the process and timings for projects to receive business model support.
- Designate a system operator with a duty to efficiently manage the network and ensure network codes and governance arrangements are established in a manner fit for this purpose.
- Set out how decisions will be taken to add additional pipeline routes to the core network, including timings and the decision making criteria for awarding development expenditure in the shorter term and business models at a later date.

Growth across all regions

17. Government should commit long term funding of £22 billion for major transport projects in cities from 2028 to 2045. The initial focus for this funding should be on those cities that are likely to have the greatest need for increased capacity, justifying investment in rail or tram type projects – the Commission’s analysis indicates that these cities are Birmingham, Bristol, Leeds and Manchester. Some of this funding should also be made available to other cities where there is likely to be a need for increased capacity or connectivity. To reflect the uncertainty over future travel demand and cost, the total investment package should be reappraised before final decisions are made on which projects to take forward.
18. To encourage modal shift and enable an increase in trips in congested cities, government should make the long term funding for major projects outlined in recommendation 17 conditional on recipient cities committing to introduce a demand management scheme, in a way that is designed to work best in the local context. The exact form and sequencing of the demand management scheme should be a decision for the individual city, and the revenue raised should be retained by the local area for investment in public transport and active travel.
19. The cities that directly benefit from the major transport projects outlined in recommendation 17 should make a significant contribution to the capital costs. Government should expect a local contribution of at least 15 to 25 per cent towards the total cost of the investment – although there are scenarios where a higher contribution may be expected, particularly for less expensive investments. Government and the UK Infrastructure Bank should work with cities to investigate and facilitate financing mechanisms and funding sources that could include a combination of business rates retention, third party contributions, forms of land value capture, and new income streams, to support the delivery of local public transport infrastructure.
20. Government needs to move faster in devolving powers and funding for local transport to local authorities. By the next Spending Review, government should have agreed single multiyear financial settlements for existing mayoral combined authorities to invest in local priorities, and then continue to roll these out to new mayoral combined authorities. All county councils and unitary authorities that remain responsible for strategic transport planning should be provided with devolved five year transport budgets by the end of 2025, sufficient to cover maintenance, renewals and small to medium enhancements.

Government should ensure that £8 billion a year is available for devolved transport budgets for local authorities outside London, consisting of a combination of central government grants and locally raised funds.

21. Government should replace short term funding deals for Transport for London with five year funding settlements, sufficient to enable both the renewal and enhancement of London transport. Government should work with the Mayor of London to establish the priorities for public transport enhancements over the next 10-20 years and reach agreement on the appropriate combination of grant support, retained business rates and local mechanisms that can be used to finance and fund them.
22. Government's first priority for roads should be to maintain the existing network by investing adequately in maintenance and renewal, including to ensure proportionate resilience to climate change impacts. Government should enhance the road network on a strategic basis, with improvements targeted at underperforming sections of the network, aligning schemes with complementary policies for economic growth and giving initial priority to interventions in regions with underperforming productivity.

By the end of 2026 and ahead of commencing work on Road Investment Strategy 4 (2030 to 2035), government should use the improvement options outlined in the Commission's analysis, alongside projects identified in partnership with sub national transport bodies, mayoral combined authorities and pan regional partnerships that unlock regional economic opportunities, to develop a pipeline of future interurban road projects over a thirty year horizon.
23. Government should prioritise maintenance and renewal of the existing rail network, ensuring proportionate resilience to climate change impacts. Government should develop a new comprehensive and long term plan for rail enhancements to address the capacity and connectivity challenges in the North and Midlands, alongside completion of East West Rail and a portfolio of targeted network enhancements across the country.
24. By the end of 2026, government should develop an integrated strategy for interurban transport to frame the development of Control Period 8 for rail (2029-34) and Road Investment Strategy 4 (2030-35). This should incorporate a long term vision for network performance and resilience, a pipeline of strategic improvements to road and rail over the next 30 years, as outlined in recommendations 22 and 23, and a plan for decarbonisation, as outlined in recommendation 13. It should also set out government's approach to harnessing the benefits of new technology and achieving environmental net gain.
25. Government should ensure that gigabit capable connectivity is available nationwide by 2030 by continuing to support network competition and market deployment, alongside delivering the £5 billion Project Gigabit programme to provide coverage to premises that are uncommercial.
26. Government must ensure the right conditions are in place to accelerate the market led deployment of 5G. By the end of 2025, government should:
 - improve the consistency of approvals for 5G masts by planning authorities, including by allocating funding for local authority digital champions and publishing a list of the best and worst performing local authorities for site approvals
 - work with Ofcom to encourage further use of the Shared Access Licence regime to speed up access to spectrum and open up opportunities for new services, including where increased power may be needed in some locations, and to ensure it supports localised private networks

- develop options for subsidising 5G coverage in uncommercial areas, should new use cases demonstrate the need for nationwide coverage.
27. Government should identify the specific telecommunications needs of the energy, water and transport sectors and ensure that infrastructure is delivered to meet these by, at the latest, 2030 for the energy and water sectors and 2035 for the road and rail sectors. Strategies for how this will be achieved must be set out by the end of 2025 for energy and water and by the end of 2026 for road and rail, including:
- the most cost effective network deployment models, and the extent to which infrastructure can be shared between different sectors
 - a spectrum authorisation approach that ensures access to adequate spectrum, whether dedicated national bands or shared spectrum for infrastructure users
 - clear responsibilities within government for delivering telecoms strategies
 - consideration of whether dedicated networks and spectrum or upgrades to existing networks can meet specific public policy goals, including consistent and reliable rail passenger connectivity.

Improving resilience and the environment

28. By 2025, government should:
- following advice from regulators, publish a full set of outcome based resilience standards for energy, water, digital, and transport 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.
29. In time to inform the next round of regulatory settlements (for water, digital and energy networks) or spending reviews (for road and rail networks and flood risk management infrastructure), government should ask infrastructure operators to estimate the costs of maintaining government resilience standards in the face of projected climate change to 2050. For sectors without formal spending settlements, such as ports and waste, these should be reported by 2029. All sectors should publicly report adaptation costs in a compulsory fifth round of Adaptation Reporting Power reports in 2029.
30. By the end of 2025 the Met Office, infrastructure operators and appropriate regulators should work together to develop an accessible interface for asset owners to use relevant climate data. In time to inform the fourth National Adaptation Plan and the fifth Climate Change Risk Assessment, government should consider whether another UK Climate Projection is needed to fill data gaps to support infrastructure operators in planning for climate adaptation.
31. By the end of 2026 government should work with the relevant standards bodies to identify and update core technical engineering standards to factor in future climate change.
32. In relation to surface water flooding, government should progress measures to control the area of impermeable surfaces, accurately identify areas where the most properties are

at risk and set a clear long term target to reduce properties at risk. The appropriate flood risk management authorities should develop single joint plans to deliver the reductions in risk. These plans should be supported by devolving funds from national budgets with local public and private contributions, particularly from water companies where their assets need to be improved to reduce the risk. Full details of the recommendations can be found in *Reducing the risk of surface water flooding*.

33. By 2025, government should set a long term measurable target to reduce the number of properties likely to be flooded by rivers or the sea. Progress against this target should be tracked using the Environment Agency's new National Flood Risk Assessment and take account of property level protection.

In setting and delivering the target, government should:

- use as a starting point the Commission's proposed standard of protection against flooding of an annual likelihood of 0.5 per cent and 0.1 per cent for densely populated areas
- make use of National Flood Risk Assessment 2 and future iterations of the Environment Agency's Long Term Investment Scenarios to quantify risk and establish targets for cost effective risk reduction
- adopt different standard of protections in local areas, where cost effective and based on discussions with affected communities
- invest in line with the profile set out by the Commission
- maximise the use of nature based and catchment solutions and consider the additional benefits beyond flood mitigation that they bring
- adequately fund wider resilience measures to prepare for and recover from flooding
- require planning authorities to ensure that from 2026 all new development is resilient to flooding from rivers with an annual likelihood of 0.5 per cent for its lifetime and does not increase risk elsewhere.

34. Government and Ofwat should ensure plans are in place to deliver additional supply and demand reduction of at least 4,000 mega litres per day. Action to deliver this twin track approach should include:

- the Regulators' Alliance for Progressing Infrastructure Development and Price Review process ensuring that at least 1,300 mega litres per day is provided by the mid 2030s through (i) additional strategic water transfers and (ii) additional supply infrastructure
- the water industry maintaining its objective to halve leakage from 2017-18 levels by 2050, with Ofwat agreeing five year commitments for each company (as part of the regulatory cycle) and reporting on progress
- the Department for Environment, Food and Rural Affairs enabling companies to implement compulsory metering beyond water stressed areas by 2025, by amending regulations as appropriate and requiring all companies to systematically roll out smart meters as a first step in a concerted campaign to reduce water demand to 110 litres per person per day and to reduce non-household usage by 15 per cent by 2050.

35. Government should require infrastructure network and asset plans for the flood management, transport and water sectors to maximise the opportunity to improve natural capital by taking an integrated and strategic approach to maintenance and renewals. Infrastructure operators in these sectors should:

- publish regular reports on the state of environmental water quality and biodiversity on their estates or affected by their assets
- develop and fund maintenance and renewal strategies that deliver a net improvement in environmental water quality and biodiversity by altering operating and maintenance regimes and materials, incorporating new design features reflective of nature based solutions, and in some cases moving spend from the development of 'new' to existing assets.

Guidance and objectives should be delivered by:

- the Department for Transport to inform National Highways' Road Investment Strategies and Network Rail's Control Period 8
- the Environment Agency as part of its enabling and supporting programmes included in the next Flood and Coastal Erosion Investment plan, due to start in 2027
- Ofwat working with the environmental regulators, to inform operation, maintenance and renewals activities in 2030-35.

36. Government should implement its waste collection reforms and materials regulations, to meet the 65 per cent recycling target by 2035, and work towards higher rates of recycling thereafter:

- without further delay, implement and provide clear guidance on how the collection reforms, known as 'simpler recycling', packaging extended producer responsibility scheme and deposit return scheme will work
- by 2026, develop individual recycling targets for all local authorities and provide financial support for transitional costs
- expand the single use plastics ban to cover a wider range of hard to recycle plastic items
- introduce a measurement system, from 2025, on the composition and waste treatment destinations for commercial and industrial waste in England. Where the market is not likely to deliver improved recycling of this waste, government should develop future policies to increase recycling rates further.

37. Government should create stronger incentives for investment in the recycling infrastructure that will be needed in the future, by banning future energy from waste capacity that does not include carbon capture and storage. Government should increase the landfill tax to ensure it remains more expensive than energy from waste. It should also limit demand for existing unabated energy from waste:

- with immediate effect, local authorities should not sign or renew long term contracts for waste services relying on energy from waste without credible plans for carbon capture and storage
- local authorities with existing long term contracts should transition away from unabated energy from waste at end of contract, or at break clauses where possible
- government should deliver its commitment to bring energy from waste into the Emissions Trading Scheme in 2028.

Making good decisions, fast

38. By 2025, government should introduce legislation to make at least five yearly reviews of the National Policy Statements for Energy, Water Resources and National Networks a legal requirement. These statements should include clear tests, refer to spatial plans and set out clear timelines and standards for consultation during the pre-application stage. Reviews should consider the appropriateness of existing and future technologies and thresholds. Government should amend legislation to bring onshore wind into the Nationally Significant Infrastructure Project system as soon as possible. By 2025, government should also set out the criteria for triggering reviews of other National Policy Statements.
39. By July 2024, government should introduce a system of modular updates to National Policy Statements linked to primary or secondary legislation to ensure clarity on how future legislative change relates to National Policy Statements.
40. By the end of 2024, the Department for Environment, Food and Rural Affairs should introduce a data sharing platform for environmental data with clear data standards, sharing relevant developer and local nature recovery strategy data. By the end of 2025 statutory consultees should develop a library of historic and natural environmental mitigations for different kinds of infrastructure. Statutory consultees should also receive and use new resource to gather baseline data and agree strategic mitigations for urgent infrastructure, firstly for wind generation and electricity transmission, and then water resources, by the end of 2025.
41. By the end of 2023, government should develop a framework of direct benefits for local communities and individuals where they are hosting types of nationally significant infrastructure which deliver few local benefits.
42. By the end of 2023, a central coordination and oversight mechanism should be developed, reporting to the Prime Minister or the Chancellor, with measurable targets for reducing consenting times for Nationally Significant Infrastructure Projects.
43. By May 2024, performance indicators for statutory consultees operating under a cost recovery model should form part of compulsory service level agreements with developers, with budget implications for failure to meet agreed service levels. Developers' applications should only be accepted for examination once a service level agreement is in place.
44. Government must empower regulators to facilitate investment in a strategic way that address the long term challenges of net zero, energy security and climate resilience by:
 - setting out a long term strategic vision for each of the regulated sectors, through strategic policy statements, updated during each Parliament
 - requiring regulators to enhance the role of competition by introducing legislation to remove any barriers to the use of competition and focusing 'standard' periodic price controls on the maintenance of existing networks and using tendering processes for strategic enhancements, with a clear, public justification required where tendering is not used.
45. The Design Group will develop further guidance that explains how design leaders, using an effective, structured process, should develop and embed project specific design principles. By 2024, the Infrastructure and Projects Authority should incorporate this guidance within its assurance review regime and expect all Nationally Significant Infrastructure Projects to follow it.

46. By 2025, government should reform public spending frameworks for infrastructure to provide longer term certainty and more effective management by:

- setting fixed budgets for capital infrastructure for at least five years
- moving away from annual controls for major capital projects and instead giving major projects a fixed budget with the ability to move money forward and backward across years within that budget
- accounting for maintenance and renewal spend separately from capital or resource spend — these budgets should be set for at least five years, with departments identifying an indicative longer term pipeline that highlights any particularly large upcoming maintenance or renewal spend
- giving infrastructure ‘megaprojects’ their own ‘project expenditure limit’ including explicit contingency budgets, separate to the department which runs them
- adopting the funding profile set out by the Commission’s recommendations in future spending reviews.

C. Glossary

Term	Meaning
1. The challenges ahead (for sector specific, see chapters 2-4)	
Economic infrastructure	The Commission's framework document defines the sectors of economic infrastructure as follows: energy, transport, water and wastewater (drainage and sewerage), waste, flood risk management and digital communications.
Expenditure deciles	This refers to household expenditure. If all households were ranked in terms of the amount of money they spend, deciles would divide this distribution into ten equal parts, where the first decile is the group of the ten per cent of households with lowest expenditure, and the tenth decile the ten per cent of households with highest expenditure.
National Infrastructure Strategy	The government's National Infrastructure Strategy was published in 2020, alongside a detailed response to the Commission's first Assessment. It set out government's plans for the UK's infrastructure.
Systems thinking	Systems thinking is a way of looking at interdependent structures within a system and understanding the relationships between them in order to better understand the complexity of the system as a whole.
2. Energy and reaching net zero	
Balancing mechanism	A market run by the electricity system operator, which pays market participants to increase supply or reduce demand over short timeframes to bring the electricity system into balance.
Capacity market	A market run by the electricity system operator, which offers long term contracts and regular payments to participants in exchange for providing reliable electricity supply if the system is under stress.
Carbon Budget	Carbon budgets specify the volume of greenhouse gases the UK can emit over a set five year period to stay on track to reach the 2050 net zero target. These are set by the government based on the advice of the Climate Change Committee and are legally binding.

Term	Meaning
Carbon capture and storage	The process of capturing carbon dioxide and storing it permanently below ground to avoid it being released into the atmosphere.
Contracts for Difference	A contract that provides a fixed price for electricity produced by low carbon electricity generators. These are issued each year through competitive auctions.
Development consent order	The permission for development of a project categorised as a Nationally Significant Infrastructure Project.
Direct electric heating	A form of heating, such as an electric radiator, which converts electricity into heat with a maximum of a one to one ratio of electricity to heat.
Energy security	The continued availability of energy at an affordable price.
Flexible technologies	Technologies that can vary the amount of electricity they use or generate based on demand signals or that can store and return electricity to the grid.
Floating offshore wind	Wind turbines installed on floating structures out at sea, kept in place by anchors.
Front end engineering design study	A study of the basic technical requirements and costs of an engineering project. These studies are completed after a conceptual design or feasibility study.
Gigawatt (GW)	A watt is a unit of measurement of the rate of energy transferred at any one point in time. One watt is equal to one joule of energy transferred per second. A gigawatt (GW) is one billion watts.
Heat loss rate	How quickly the heat inside a building is lost to the outside environment through walls and windows and via drafts through gaps. This is used to help calculate the required size of a heating system.
Heat network (including district heat)	A network of pipes supplying hot water for heating from a central source to multiple buildings (district heat networks) or to multiple dwellings in the same building (communal heat networks).

Term	Meaning
Heat pump	A technology which transfers heat from a source (such as the outside air, ground or water) and concentrates it so it can be used for heating and hot water. As heat pumps transfer heat rather than generate it, they are more efficient than other heating systems. They circulate water around a heating system at a lower temperature than gas boilers, but 'high temperature' heat pumps can output water at higher temperatures.
Independent System Operator	Also referred to as the Future System Operator. This will be a new public body which takes on the roles of the current electricity system operator, which is owned by National Grid. The future system operator will be responsible for ensuring that electricity supply and demand balance at all times. It will also take on new coordination and planning roles for the electricity and gas systems.
Industrial cluster	A region with multiple industries near each other which manufacture large or heavy goods and emit large amounts of carbon dioxide.
Low carbon hydrogen	Hydrogen manufactured with significantly lower carbon emissions than current manufacturing techniques. This can either be hydrogen created from electrolysis using low carbon electricity (green hydrogen), or from natural gas with carbon capture and storage (blue hydrogen).
Modular reactors (small or advanced)	These are nuclear reactors that are smaller than conventional ones. They are made in a factory and transported to where they will be used.
Price control	Price controls are set by Ofgem and balance the investment in electricity and gas networks, company returns and the amount companies charge for operating their network.
Rapid charge point	Rapid charge points, of 25-100kW, can charge an electric vehicle battery in 20 minutes to an hour.
Regulated asset base model	The regulated asset base model provides revenue certainty for private sector infrastructure providers. The developer company receives a license from an independent economic regulator to charge consumers a set price for building new infrastructure. The price is set based on an agreed level of allowed revenue and can vary over time.

Term	Meaning
Social tariff	A cheaper tariff for people who might otherwise be unable to afford a good or service. Social tariffs can be funded by government, the companies that provide the good or service, or a combination of both.
Strategic spatial energy plan	A coordinated plan for energy networks by the independent system operator, setting out when and where upgrades are needed to meet future demand.
Terawatt hour (TWh)	A watt hour is a measure of energy. It is equal to the energy transferred by one watt of energy over one hour. A Terawatt hour is one trillion watts produced or consumed over an hour.
Town gas	A gas produced from coal, used for heating before natural gas came into use.
Unabated gas fired generation	Generation of energy from gas, which releases carbon dioxide, without any form of carbon capture to capture these emissions.
Wholesale market	The markets where electricity and gas are sold by generating companies to suppliers before being delivered to consumers.
3. Growth across regions	
Active travel	A mode of travel that involves a level of physical activity. This includes walking, cycling, trips made by wheelchair, mobility scooters, adapted cycles, e-bikes, scooters and cycle sharing schemes.
Agglomeration	The geographic concentration of economic activity, for example in city centres, and the economic benefits that are generated from businesses and people being located close to one another.
Bus rapid transit	A bus based transit system that provides for faster, more reliable and higher quality journeys than a conventional bus service. This can involve the use of segregated busways and prioritisation of buses and other high capacity vehicles over other traffic.
Capacity	The number of seats and standing spaces on buses, trams and railways.

Term	Meaning
Congestion charging	Any scheme where a fee is charged for cars or other vehicles to access an area, usually in a city. A cordon based congestion charge refers to cars or other vehicles being charged a fee if they access the area inside the cordon.
Connected and autonomous vehicles	Connected vehicles can communicate with their surrounding environment. Autonomous vehicles can operate with little or no human input (be driverless) for some, or all, of the journey. Connected and autonomous vehicles can do both.
Connectivity	The ability of people and businesses to access what they need and want. For transport networks, this refers to the ability of people to get from one place to another. For digital networks, this refers to the ability of people, businesses or devices to communicate remotely over telecoms networks.
Fiscal devolution	The ability of local levels of government to raise revenue through local tax raising powers.
Gigabit capable broadband	Broadband connections capable of delivering download speeds of at least one gigabit per second (1,000 megabits per second).
Locally led infrastructure strategies	Long term strategies, that consider the transport needs for an area alongside other infrastructure, which are developed by people who understand the needs and strengths of an area and can take account of local context.
Major road network	England's busiest and most economically important local authority 'A' roads. This tier of roads sits between the strategic road network (see below) and the rest of the local road network.
Radio spectrum	A part of the electromagnetic spectrum which supports wireless communication.
Rolling stock	Trains and carriages that are used on rail and tram systems.
Shared access license	Shared access licences are part of Ofcom's framework for enabling shared use of spectrum and allow people and business access to spectrum on a localised basis.

Term	Meaning
Shared Rural Network agreement	An agreement between the UK government and mobile industry announced in March 2020 to improve rural mobile coverage by 2025.
Smart grids	An electricity network that uses telecoms technology to monitor and respond to changes in supply and usage.
Spectrum	See 'Radio spectrum'.
Strategic road network	Nationally significant roads – motorways and major 'A' roads – which connect the main centres of population in England.
4. Improving resilience and the environment	
Anaerobic digestion	The process whereby microorganisms break down plant and animal materials in the absence of air. Produces biogas, which can be used as a fuel, and a solid digestate that can be used as a fertiliser.
Biodiversity net gain	An approach to development and/or land management which aims to leave biodiversity in a measurably better state than it was beforehand.
Biogas	Also known as biomethane. A gas that is produced through anaerobic digestion of organic materials, and which can be used as a fuel.
Biogenic waste	Organic waste, including food waste, garden waste, paper and card and agricultural waste. Produces carbon dioxide when incinerated, and methane when landfilled or anaerobically digested. Because organic waste emits carbon emissions through natural rather than human processes, if these gases are captured they can contribute to negative carbon emissions.
Cascade failure	A failure in one system which causes a failure in an interconnected system, such as a power cut preventing trains from operating.
The Climate Resilience Demonstrator (CReDo)	A climate change adaptation digital twin project that looks at the impact of flooding on energy, water and telecoms networks.
Commercial and industrial waste	Includes waste collected from businesses such as hospitality and retail, as well as waste generated during industrial production.

Term	Meaning
Construction and demolition waste	Made up of materials such as wood, steel, concrete, glass and masonry, dredging spoils, and inert materials such as soils from excavation.
Ecosystem services	Flows of goods and services provided by the natural environment that provide direct and indirect benefits to society. Examples include food, clean air and water, recreation, climate regulation and flood protection.
Embankment failure	The failure of an earthwork embankment which rail or road infrastructure sits on top of, or cuts through. This can lead to the collapse of road paving or rail tracks, or landslips obstructing them.
Emissions Trading Scheme	A 'cap and trade' scheme for reducing greenhouse gas emissions. Firms must buy credits for each unit of emissions they produce, and can sell or trade credits that they do not need. Supply of credits is controlled by government. This ensures that the price is sufficiently high to incentivise firms that can reduce their emissions to do so.
Energy from waste	Production of electricity, heat and/or fuel from residual waste.
Environmental net gain	An approach to development that goes further than biodiversity net gain, requiring the natural environment to be left in a measurably better state than it was beforehand.
Environmental water quality	The health of rivers, lakes, the sea and water in aquifers and their ability to support human and wildlife needs. Considers the physical, chemical and biological nature of the water and its volume or level of flow.
Flexible tariffs	A method of billing for water where the price changes under different circumstances, such as charging more per litre for water use above a certain level, or setting higher prices in the event of drought conditions.
Gate fees	Charged by waste treatment providers to accept and process waste.
Internal Drainage Board	Independent public authorities that manage water levels in low lying, mostly rural areas, to protect agriculture and the environment.
Landfill	Where residual waste that cannot be recycled or incinerated is buried in the ground. Any liquid that leaches out, or gas that is released, is collected and disposed of separately.

Term	Meaning
Local authority collected waste	All waste collected by local authorities including waste from households, bulky waste, and from street bins, street sweepings and parks and grounds.
Materials Recycling Facility	Sometimes also called a Materials Recovery Facility, these are plants that sort, prepare and reprocess collected recycling to create new materials for manufacturing.
Mechanical Biological Treatment	A treatment process that separates residual waste into recylates, refuse derived fuels for energy recovery, and biodegradable slurries for composting and anaerobic digestion.
Megalitre	A unit of capacity equal to a million litres.
Organic waste	Waste from living organisms. This includes food waste, garden waste, paper and card and agricultural waste
Outcome based resilience standard/ service standard	A standard which sets the expected level of service users can expect from infrastructure networks. This can include differential recovery standards in extreme events such as storms.
Regulatory settlement	Multiyear settlements between regulators and infrastructure operators in the water, energy and digital sectors. In different ways, these settlements determine the cost of utility bills and the extent of investment in infrastructure networks.
Residual waste	Non hazardous waste that cannot be recycled and must be sent to energy recovery or disposal.
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.
Surface water flooding	Surface water flooding – also referred to as pluvial or flash flooding – happens when there is so much rain that it cannot drain away quickly enough, either because drainage networks reach capacity and overflow, or because they are not operating at full capacity due to blockages in pipes and sewers, or in above ground drainage like gullies.

Term	Meaning
Sustainable drainage	Sustainable drainage uses natural processes to catch, drain or store water above ground – reducing the amount of water that enters underground sewers. Permeable paving, ponds and rain gardens are examples of sustainable drainage.
Upper tier local authority	In areas with two tiers of local government (district and county councils), this means the county council. In areas with one tier of local government, it means the unitary authority.
Waste hierarchy	The waste hierarchy ranks waste management options from the least to the most environmentally harmful. It is a legal requirement for businesses and organisations that produce or handle waste.
Water abstraction	Taking water from rivers, lakes and the sea for public consumption.
Water supply infrastructure	Infrastructure which increases the amount of water available for consumption either through storage, such as reservoirs, transfer or additional treatment, such as desalination plants.
5. Investing for the future	
Distributional impacts	The impact, in terms of costs and benefits, on specific groups of the population, in particular different groups of people with varying levels of household income.
Fiscal remit	The government's remit letter for the Commission states that it must be able to demonstrate that its recommendations for economic infrastructure are consistent with, and set out how they can be accommodated within, gross public investment in economic infrastructure of between 1.1 per cent and 1.3 per cent of GDP in each year between 2025 and 2055.
Household spending on infrastructure	Total household expenditure on infrastructure, including bills for water, energy, telecoms and the cost of fuel for transport, capital expenditure on cars, heating systems, gas boilers and other household infrastructure assets.

Term	Meaning
6. Making good decisions, fast	
Capital infrastructure project	A long term infrastructure project that will build, improve or maintain a physical asset, such as a railway line or a sewer system.
Financially sustainable	A company that is able to consistently earn enough revenue or returns on investment to at least cover its costs.
Megaprojects	An extremely large scale investment project, typically with very high costs associated (in the billions of pounds).
Modules	An attachment updating a National Policy Statement which is focussed on a specific topic.
National Policy Statements	National Policy Statements are statutory documents published under the Planning Act 2008 that set out national policy on particular types of nationally significant infrastructure projects. They establish the need for specific types of development and provide the framework within which the Secretary of State makes decisions on giving development consent for nationally significant infrastructure project applications.
Nationally Significant Infrastructure Projects	Large scale developments in England relating to energy, transport, water or waste which require development consent under the Planning Act 2008.
Reference class forecasts	Reference class forecasts predict likely future outcomes by looking at similar past situations and their outcomes. It is usually used to assess levels of confidence in project budgets.
Spending Review	Government Spending Reviews determine how much is spent on public services, setting budgets for departments over a multi-year period, and setting out the key things this money will be spent on.
Statutory consultees	Organisations and bodies, defined by statute, that must be consulted on relevant planning applications. They help ensure development best meets the needs of the local area, including of the surrounding natural and built environment. They include government departments, charities, and other organisations.

Term	Meaning
Strategic Policy Statements	Strategic Policy Statements are statutory documents in which the Secretary of State sets out strategic priorities and objectives for regulators to follow in carrying out their functions, alongside their existing duties.

D. Acknowledgements

The Commission would like to thank all the organisations that engaged with the process of developing the second National Infrastructure Assessment. It would like to extend particular thanks to the following organisations listed below.

The Commission is also grateful to those who responded to consultations, commented on drafts, participated in workshops and roundtables, or otherwise engaged with the Assessment. It is also grateful to the members of the public who took part in social research workshops and polling.

Bridget Rosewell and David Fisk were members of the Commission at earlier stages of the Assessment process and the Commission is grateful for their contributions.

The Commission would like to thank its expert advisory panels, the Design Group, and the Young Professionals Panel, who have all contributed to the development of this report. More details on each of these groups and their members can be found on the Commission's website.

The Commission acknowledges the contributions of the consultants engaged by the Commission, that contributed to developing its evidence base. Many of these organisations produced supplementary documents that can be found on the Commission's website.

The Commission would also like to thank all the members of the secretariat (past and present) who contributed to or helped with this report and analysis: Sahra Abdirahman, Mark Ardrone, Ed Beard, Rita Beden, Kath Boulter, Carl Brewer, Hannah Brown, Leo Camacho, Joanna Campbell, Jonathan Chappell, Mark Clarke, Jen Coe, Sophie Donaldson, Christopher Durham, David Elphick, Rose Galloway Green, Alex Goodwin, James Harris, James Heath, Cilla Hellgren, Joe Highton, Helen Hill, Verity Hillier, David Hodcroft, Tom Hughes, Nadir Hussain, Aidan Irwin-Singer, Andrew Jones, Catherine Jones, Charley Lamb, Harriet Lee, Rob Mallows, Kirin Mathias, Greg McClymont, Ryan McGowan, Benjamin McNamee, Genelva Meikle, David Menzies, Catherine Neil, Vasilis Papakonstantinou, Jack Parker, Joanna Pearce, David Pegg, Beverley Pool, Nick Prentice, Shah Rahman, Margaret Read, James Richardson, Thomas Schiller, Néha Shah, Zeinab Shaikh, Grace Shaw, Daniel Shotter, Yasmin Sooby, Giles Stevens, Luke Sweeney, Monika Szczyrba, Lyudmyla Tautiyeva, Charles Wain, Christopher Wanzala-Ryan, Clara Wikforss, Ben Wilson, Karen Winn, Nathan Wyatt and Zineb Ziani. Special thanks go to the Environment Agency and the Greater Manchester Combined Authority who provided secondees to work on the Assessment.

Addleshaw Goddard LLP

AKT II

Ambition Lawrence Weston

Anaerobic Digestion and
Bioresources Association

Analysys Mason

Anglian Water

Arup

Association of British Ports

Association for Consultancy
and Engineering

Association for Decentralised
Energy

Association for Project
Management

Association of Directors of Environment, Economy, Planning & Transport	Centrica	Disabled Persons Transport Advisory Group
Association of SuDS Authorities	Chartered Institution of Wastes Management	Dorset Council
Aurora Energy Research	Chartered Institution of Water and Environmental Management	E3G
Barking Riverside Ltd	Citizens Advice	Electricity North West
Black Country Industrial Cluster	City Group Ltd	Ellen MacArthur Foundation
Birmingham City Council	CityFibre	Energy Networks Association
Bristol City Council	Climate Change Committee	Energy Systems Catapult
Bristol City Leap	Confederation of British Industry	Energy Transitions Commission
British Chambers of Commerce	Confederation of British Industry East of England	Energy UK
British Geological Survey	Construction Industry Council	enfinium
British Standards Institution	Core Cities UK	Environment Agency
BT Group	Cornwall Council	Environmental Services Association
Business West	Coventry University	Expedition Engineering
BusinessLDN	Dar Group	Flood Re
Cabinet Office	Department for Business and Trade	Foot Anstey LLP
Cadent Gas	Department for Energy Security and Net Zero	FutureGrid
Cambridgeshire & Peterborough Combined Authority	Department for Environment, Food and Rural Affairs	Global Infrastructure Investment Association
Carbon Capture and Storage Association	Department for Levelling Up, Housing and Communities	Grant Associates
Centre for Cities	Department for Science, Innovation and Technology	Greater Birmingham Chambers of Commerce
Centre for Energy Policy, University of Strathclyde	Department for Transport	Greater London Authority
Centre for Local Economic Strategies	Design Council	Greater Manchester Centre for Voluntary Organisation
Centre for Research into Energy Demand Solutions	Digital Catapult	Greater Manchester Chamber of Commerce
		Greater Manchester Combined Authority
		Greater Manchester Equality Alliance

Green Alliance	Lower Thames Crossing	Office for Environmental Protection
Historic England	Major Projects Association	Ofgem
HM Treasury	Manchester City Council	Ofwat
Hydrogen UK	Marine Management Organisation	Ørsted
Imperial College London	Material Focus	Pinsent Masons
Industrial Decarbonisation Research and Innovation Centre	Met Office	Planning Inspectorate
Infrastructure and Projects Authority	Midlands Connect	Policy Connect
Infrastructure Client Group	Mills & Reeve	RAC Foundation
Infrastructure Operators Adaptation Forum	National Audit Office	Regen
Institute for Government	National Gas	ReLondon
Institute of Asset Management	National Grid	RenewableUK
Institution of Civil Engineers	National Grid ESO	Resilience Rising
Institution of Mechanical Engineers	National Highways	Resolution Foundation
ITM Power	National Infrastructure Planning Association	Royal Institute of British Architects
KCOM	National Water Resources Framework Senior Steering Group	Royal Society
Kent County Council	Natural England	Royal Society of Arts
KPMG	Network Rail	Sayers and Partners
Landscape Institute	Newcastle University	Scottish Government (Riaghaltas na h-Alba)
Leeds City Council	North London Waste Authority	ScottishPower
Local Authority Recycling Advisory Committee	North Sea Transition Authority	Severn Trent
Logistics UK	North Yorkshire Council	SGN
London Borough of Hillingdon	Northern Gas Networks	Somerset Drainage Boards Consortium
London Councils	Northern Ireland Executive	South Gloucestershire Council
London School of Economics and Political Science	Northumbrian Water	SSE
	Octopus Energy	Stantec
	Ofcom	Sustainability First

Tees Valley Combined Authority	U+I	Vodafone
Teesworks	UK Centre for Ecology and Hydrology	Wales and West Utilities
Thalia Waste Management	UK Energy Research Centre	Waste and Resources Action Programme
Thames Water	UK Infrastructure Bank	Water UK
The Briefing Circle	UK Power Networks	Welsh Government (Llywodraeth Cymru)
The Crown Estate	United Utilities	Wessex Regional Flood and Coastal Committee
The Infrastructure Forum	University of Cambridge	Wessex Water
The Wildlife Trusts	University of Leeds	West and North Yorkshire Chamber of Commerce
Three	University of Manchester	West Midlands Combined Authority
Transport for Greater Manchester	University of Oxford	West Yorkshire Combined Authority
Transport for London	University of Sheffield	Wildlife and Countryside Link
Transport for the North	University of Strathclyde	Yorkshire Water
Transport for West Midlands	University of Warwick	
Transport North East	Veolia	
Treveth Holdings LLP	Virgin Media O2	
	Viridor	

Remit and structure of the Commission

The National Infrastructure Commission was established as an executive agency of the Treasury to provide impartial, expert advice and make independent recommendations to the government on economic infrastructure. The Commission operates independently, at arm's length from government.

The Commission's purpose, and its principal outputs, accountabilities and duties are set out in its Charter and accompanying Framework Document.

The inaugural Framework Document published in 2016 committed government to reviewing the Commission's performance of its core objectives and responsibilities within five years. This review was conducted during 2021 and is reflected in a revised and enhanced set of objectives and fiscal remit for the Commission, set out below. The date of the next such review will be no later than 2026.

The Commission's remit covers all sectors of economic infrastructure: energy, transport, water and wastewater (drainage and sewerage), waste, flood risk management and digital communications. The Commission also considers potential interactions between its infrastructure recommendations and housing supply; and between its recommendations and the government's legal target to halt biodiversity loss by 2030. This explicit biodiversity consideration was added in 2021. Housing supply itself, other social infrastructure such as schools, hospitals or prisons, and agriculture and land use are all outside the remit of the Commission.

The Commission's objectives are to: 1) support sustainable economic growth across all regions of the UK, 2) improve competitiveness, 3) improve quality of life, and 4) support climate resilience and the transition to net zero carbon emissions by 2050. The latter objective was added in 2021.

In fulfilling its purpose and objectives, the Commission seeks to:

- 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.

The Commission delivers the following products and services:

- a National Infrastructure Assessment once in every Parliament, setting out the Commission's assessment of long term infrastructure needs with recommendations to government
- specific studies on pressing infrastructure challenges as set by the government, taking into account the views of the Commission and stakeholders; these studies will include recommendations to government
- an Annual Monitoring Report (styled as an Infrastructure Progress Review), taking stock of the government's progress in areas where it has committed to taking forward recommendations of the Commission.

The Commission's binding fiscal remit requires it to demonstrate that all its recommendations for economic infrastructure are consistent with, and set out how they can be accommodated within, gross public investment in economic infrastructure of between 1.1 per cent and 1.3 per cent of GDP each year between 2025 and 2055. The fiscal remit was previously between 1.0 per cent and 1.2 per cent of GDP. The Commission's reports must also include a transparent assessment of the impact on costs to businesses, consumers, government, public bodies and other end users of infrastructure that would arise from implementing its recommendations.

When making its recommendations, the Commission is required to take account of both the role of the economic regulators in regulating infrastructure providers and the government's legal obligations, such as carbon reduction targets. The Commission's remit letter also requires the Commission to ensure that its recommendations do not reopen decision making processes where programmes and work have been decided by the government or will be decided in the immediate future.

The Infrastructure and Projects Authority, a separate body, is responsible for ensuring the long term planning carried out by the Commission is translated into successful project delivery, once the plans have been endorsed by government.

The Commission's remit extends to economic infrastructure within the UK government's competence. Across much of the Commission's remit there is currently substantial devolution to Northern Ireland, Scotland and Wales. The Commission's role is to advise the UK government, but the Commission works with both the UK government and the devolved administrations where responsibilities interact.

Table: Devolved administration responsibilities, by infrastructure sector

Sector	Devolved administration responsibility		
	Northern Ireland	Scotland	Wales
Digital	Reserved	Reserved	Reserved
Energy	Devolved, except nuclear	Reserved, except energy efficiency	Reserved, except energy efficiency
Flood risk	Devolved	Devolved	Devolved
Transport	Devolved	Largely devolved	Devolved, except rail
Waste	Devolved	Devolved	Devolved
Water and sewerage	Devolved	Devolved	Devolved

The Commission's members

The National Infrastructure Commission comprises a Chair and between four and 12 additional non-executive Commissioners.

The current members of the Commission are:



Sir John Armitt CBE (Chair) published an independent review on long term infrastructure planning in the UK in September 2013, which resulted in the National Infrastructure Commission. Sir John was Chief Executive of Costain from 1997 until 2001, after which he served as Chief Executive of Railtrack (later Network Rail) until 2007. From 2007 he was Chair of the Olympic Delivery Authority.



Julia Prescott (Deputy Chair) is Co-Founder of Meridiam Infrastructure, a member of the UK Investment Council and Co-Chair of the Global Infrastructure Facility, a G20, World Bank and multilateral bank promoted organisation. She is also Chair of the Fulcrum Infrastructure Group and Neuconnect Limited, Deputy Chair at the Port of Tyne and a non executive director of Allego NV, an electric car charging company.



Professor Sir Tim Besley CBE is School Professor of Economics and Political Science and W. Arthur Lewis Professor of Development Economics at the LSE. From September 2006 to August 2009, he served as an external member of the Bank of England Monetary Policy Committee.



Neale Coleman CBE is a co-founder of Blackstock Partnership. He worked at the Greater London Authority from 2000-2015 leading the Mayor's work on London's Olympic bid, the delivery of the games, and their regeneration legacy. Neale has also served as Policy Director for the Labour Party.



Andy Green CBE holds several Chairman, Non-Executive Director and advisory roles, linked by his passion for how technology transforms business and our daily lives. He chairs Lowell, a major European credit management company and has served as Chair for the Digital Catapult, an initiative to help grow the UK digital economy.



Professor Jim Hall FrEng is Professor of Climate and Environmental Risks in the University of Oxford and Director of the University's Environmental Change Institute. He is internationally recognised for his research on risk analysis and decision making under uncertainty for water resource systems, flood and coastal risk management, infrastructure systems and adaptation to climate change.



Professor Sadie Morgan OBE is a founding director of the Stirling Prize winning architectural practice dRMM. She is also Chair of the Independent Design Panel for High Speed Two and is a Mayor's design advocate for the Greater London Authority. She sits on the boards of the Major Projects Association and Homes England.



Kate Willard OBE is the Thames Estuary Envoy and chairs the Thames Estuary Growth Board. Since 2017 she has served as Chair for the Arts Council England's Area Council North. In addition, she is an independent consultant working on a diverse portfolio of infrastructure and growth projects. In March 2022 she was appointed Chair of Teesside International Airport.



Nick Winser CBE has had a 30-year career in the energy sector, including serving as UK and European CEO of the Board of National Grid and President of the European Network of Transmission System Operators for Electricity. He currently serves as Chair of the Energy Systems Catapult.

The Commission's Young Professionals Panel

The Young Professionals Panel was first established in 2018, bringing together a group of infrastructure, economics and engineering professionals at an early stage of their careers. A first cohort served between 2018 and 2020, and a second between 2020 and July 2023. Successive cohorts have worked to both support and inform the Commission's work, raising awareness among younger audiences and challenging the Commission's thinking with fresh perspectives.

Each panel has devised their own work plan, creating their own content independently of the Commission while also attending some Commission meetings and liaising with the secretariat on specific projects. Outputs from the panel's work can be found on the Commission website,⁵²⁷ including editions of their *Infra[un]structured* podcast and opinion pieces cutting across sectoral boundaries and traditional approaches, offering ideas for the future.

The National Infrastructure Design Group

The National Infrastructure Design Group was established in 2019 to inspire renewed ambition for the quality of the UK's infrastructure. It is chaired by commissioner Professor Sadie Morgan OBE. Its mission is to inspire, promote and champion design excellence in all nationally significant infrastructure projects. It is a non-executive advisory group to the National Infrastructure Commission.

The Design Group supported the development of proposals within the second National Infrastructure Assessment and continues to provide advice and guidance to the Infrastructure and Projects Authority and other partners as they implement the design recommendations from the first Assessment. Further details about the Group can be found on the Commission website.⁵²⁸

References

1. The challenges ahead

- 1 HM Treasury (2020), [National Infrastructure Strategy](#)
- 2 HM Government (2022), [Levelling Up the United Kingdom](#); Ofcom (2023), [Connected Nations update: Spring 2023](#)
- 3 Department for Energy Security and Net Zero (2023), [Energy Trends: UK electricity](#)
- 4 HM Government (2022), [Taking charge: the electric vehicle infrastructure strategy](#)
- 5 Department for Environment, Food and Rural Affairs (2021), [Flood and coastal erosion risk management: an investment plan for 2021 to 2027](#)
- 6 HM Treasury (2020), [National Infrastructure Strategy](#)
- 7 UK Infrastructure Bank (2022), [Strategic Plan](#)
- 8 HM Treasury (2021), [Autumn Budget and Spending Review 2021](#)
- 9 Department for Transport (2023), [Monthly total number of electric vehicle public charging devices available in the UK](#)
- 10 National Infrastructure Commission (2021), [The Second National Infrastructure Assessment: Baseline Report](#)
- 11 Environment Agency (2023), [Flood and Coastal Erosion Risk Management Report: 1 April 2022 to 31 March 2023](#)
- 12 Environment Agency (2023), [Water and Sewerage Companies in England: Environmental performance report 2022](#) and HM Government (2021), [25 Year Environment Plan Annual Progress Report, April 2020 to March 2021](#)
- 13 Climate Change Committee (2023), [Progress in adapting to climate change: 2023 Report to Parliament](#)
- 14 Department for Environment, Food and Rural Affairs (2023), [UK Statistics on Waste](#); Climate Change Committee (2020), [The Sixth Carbon Budget: Waste](#)
- 15 Rodrigues & Breach (2021), [Measuring Up](#), Centre for Cities
- 16 National Infrastructure Commission (2021), [The Second National Infrastructure Assessment: Baseline Report](#)
- 17 Department for Energy Security and Net Zero (2023), [Policy paper: Energy Price Guarantee up until 30 June 2023](#)
- 18 Ofgem (2019), [Letter: Default tariff cap update for 1 April 2019](#)
- 19 House of Commons Library (2023), [Rising cost of living in the UK](#)
- 20 HM Treasury (2010), [Infrastructure Cost Review: Main Report](#)
- 21 Office for National Statistics (2023), [Construction output price indices](#)
- 22 Infrastructure and Projects Authority (2021), [Transforming Infrastructure Performance: Roadmap to 2030](#)
- 23 HM Treasury (2021), [Remit letter to the National Infrastructure Commission](#)
- 24 HM Government (2023), [Carbon Budget Delivery Plan](#)
- 25 Climate Change Committee (2023), [Progress in reducing emissions, 2023 Report to Parliament](#)
- 26 Climate Change Committee (2023), [Progress in reducing emissions, 2023 Report to Parliament](#)
- 27 Climate Change Committee (2023), [Progress in reducing emissions, 2023 Report to Parliament](#)
- 28 Climate Change Committee (2023), [Progress in reducing emissions, 2023 Report to Parliament](#)
- 29 Department for Energy Security and Net Zero (2023), [Final UK greenhouse gas emissions national statistics: 1990 to 2021](#); Department for Energy Security and Net Zero (2023), [Power Up Britain charts and tables](#)
- 30 The Economy 2030 Inquiry (2022), [Stagnation nation: Navigating a route to a fairer and more prosperous Britain](#)
- 31 National Infrastructure Commission (2021), [The Second National Infrastructure Assessment: Baseline Report](#); IFS Deaton Review of Inequalities (2022), [Spatial disparities across labour markets](#)
- 32 The Economy 2030 Inquiry (2022), [Stagnation nation: Navigating a route to a fairer and more prosperous Britain](#)
- 33 Centre for Cities (2020), [Why big cities are crucial to 'levelling up'](#)

- 34 National Infrastructure Commission (2021), [Infrastructure, Towns and Regeneration](#)
- 35 OECD (2020), [Enhancing Productivity in UK Core Cities](#); Centre for Cities (2020), [Why big cities are crucial to 'levelling up'](#); Stansbury, Turner and Balls (2023), [Tackling the UK's regional economic inequality: Binding constraints and avenues for policy intervention](#); McCann (2023), [The productivity performance of different types of UK regions and the challenges of levelling up](#), National Institute Economic Review
- 36 The Office for National Statistics (2022), [Productivity in towns and travel to work areas, UK: 2019](#)
- 37 OECD (2020), [Enhancing Productivity in UK Core Cities](#); Centre for Cities (2020), [Why big cities are crucial to 'levelling up'](#); Stansbury, Turner and Balls (2023), [Tackling the UK's regional economic inequality: Binding constraints and avenues for policy intervention](#); McCann (2023), [The productivity performance of different types of UK regions and the challenges of levelling up](#), National Institute Economic Review
- 38 As set out in the Commission's 2020 [Rail Needs Assessment for the Midlands and the North](#), regional disparities are caused by many interrelated issues, including skills, and other factors such as the availability of good housing, schools and city services also affect outcomes.
- 39 Frontier Economics (2017), [Exploring the economic benefits of strategic roads. Report produced for Department for Transport](#)
- 40 Stansbury, Turner & Balls (2023), [Tackling the UK's regional economic inequality: Binding constraints and avenues for policy intervention](#); Rodrigues & Breach (2021), [Measuring Up](#), Centre for Cities
- 41 National Infrastructure Commission (2021) [Second National Infrastructure Assessment: Baseline Report](#)
- 42 National Infrastructure Commission (2020), [Rail Needs Assessment for the Midlands and the North – Final Report](#)
- 43 National Infrastructure Commission (2021), [The Second National Infrastructure Assessment: Baseline Report](#)
- 44 Koutroumpis (2018), [The economic impact of broadband: evidence from OECD countries](#). Other studies have found strong links between broadband rollout and economic growth. The roll out of broadband infrastructure in OECD countries from 1997 to 2007 increased per capita growth by 0.9 to 1.5 percentage points for a ten percentage point increase in broadband penetration according to Czernick, Falck, Kretschmer and Woessmann (2011), [Broadband Infrastructure and Economic Growth](#), Economic Journal.
- 45 Regen (2023), [Building a GB electricity network ready for net zero](#)
- 46 Department for Levelling Up, Housing and Communities (2023), [Long-term Plan for Housing](#)
- 47 National Infrastructure Commission (2021), [The Second National Infrastructure Assessment: Baseline Report](#)
- 48 National Infrastructure Commission (2021), [The Second National Infrastructure Assessment: Baseline Report](#); National Infrastructure Commission (2023), [Infrastructure Progress Review](#)
- 49 The Climate Change Committee found that only 31 per cent of infrastructure operators had a good understanding of interdependency risks. Climate Change Committee (2022), [Understanding Climate Risks to UK Infrastructure: Evaluation of the Third Round of the Adaptation Reporting Power – July 2022](#)
- 50 Thinks Insight & Strategy (2023), [Social research for the National Infrastructure Commission to inform the second National Infrastructure Assessment](#)
- 51 Dasgupta (2021), [The Economics of Biodiversity: The Dasgupta Review](#); Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2019), [Nature's Dangerous Decline 'Unprecedented'; Species Extinction Rates 'Accelerating'](#)
- 52 Joint Nature Conservation Committee (2023), [Overview of Assessment of Change for all Indicators](#)
- 53 National Infrastructure Commission (2021), [Natural capital and environmental net gain: A discussion paper](#)
- 54 HM Government (2018), [A Green Future: Our 25 Year Plan to Improve the Environment](#). This has been followed up with the [Environment Act 2021](#) and the [Environmental Improvement Plan 2023](#).
- 55 HM Government (2018), [A Green Future: Our 25 Year Plan to Improve the Environment](#)

- 56 The Commission's discussion paper of Natural Capital discusses natural capital impacts on the economy and quality of life: National Infrastructure Commission (2021), [Natural capital and environmental net gain: A discussion paper](#).
- 57 PwC (2021), [NIA2 Social Research: Final report](#)
- 58 PwC (2021), [NIA2 Social Research: Final report](#)
- 59 PwC (2021), [NIA2 Social Research: Final report](#)
- 60 Thinks Insight & Strategy (2023), [Social research for the National Infrastructure Commission to inform the second National Infrastructure Assessment](#)
- 61 Thinks Insight & Strategy (2023), [Protected characteristics and infrastructure: social research to inform the National Infrastructure Commission](#)
- 62 HM Government, [Equality Act 2010](#). The protected characteristics set out in the Equality Act 2010 are: age, gender reassignment, being married or in a civil partnership, being pregnant or on maternity leave, disability, race, religion or belief, sex and sexual orientation.
- 63 Jong, Tsvetkova, Lembcke and Ahrend (2021), [A comprehensive approach to understanding urban productivity effects of local governments: Local autonomy, government quality and fragmentation](#), OECD Regional Development Papers
- 64 Systems thinking is a framework for seeing the interconnections in a system and a discipline for understanding the relevant aspects of the whole system. Government Office for Science (2022), [Systems thinking: An Introductory Toolkit for Civil Servants](#)

2. Energy and reaching net zero

- 65 Department for Energy Security and Net Zero (2023), [Digest of UK Energy Statistics](#)
- 66 Department for Energy Security and Net Zero (2023), [Digest of UK Energy Statistics](#)
- 67 North Sea Transition Authority (2023), [NSTA Overview 2023](#)
- 68 Office for Budget Responsibility (2023), [Fiscal risks and sustainability](#)
- 69 Office for Budget Responsibility (2023), [Fiscal risks and sustainability](#)
- 70 The Royal Society (2021), [Effects of net-zero policies and climate change on air quality](#)
- 71 European Federation for Transport and Environment and BloombergNEF (2021), [Hitting the EV inflection point](#)
- 72 National Grid (2023), [History of electricity in Britain](#)
- 73 Williams (1981), A History of the British Gas Industry
- 74 Department for Energy Security and Net Zero (2023), [Digest of UK Energy Statistics, Table 5.11 for 2005](#)
- 75 Department for Energy Security and Net Zero (2023), [Digest of UK Energy Statistics](#)
- 76 Aurora Energy Research (2023), [The impact of decarbonising heating in the power sector \(C\)](#)
- 77 Aurora Energy Research (2023), [The impact of decarbonising heating in the power sector \(C\)](#)
- 78 Aurora Energy Research (2023), [The impact of decarbonising heating in the power sector \(C\)](#)
- 79 Department for Energy Security and Net Zero (2023), [Powering up Britain](#)
- 80 Department for Energy Security and Net Zero (2023), [Electricity Generation Costs 2023](#)
- 81 Aurora Energy Research (2023), [The impact of decarbonising heating in the power sector \(C\)](#)
- 82 Aurora Energy Research (2023), [The impact of decarbonising heating in the power sector \(C\)](#)
- 83 National Infrastructure Commission (2018), [National Infrastructure Assessment](#)
- 84 Department for Energy Security and Net Zero (2022), [Contracts for Difference](#)
- 85 Department for Energy Security and Net Zero (2023), [Contracts for Difference \(CfD\) Allocation Round 5: results](#)
- 86 UK Energy Research Centre (2022), [Response to the Second National Infrastructure Assessment Baseline Report](#)

- 87 Commission analysis of Aurora Energy Research (2023), [The role of system flexibility in achieving net zero \(A\)](#)
- 88 Aurora Energy Research (2023), [The role of system flexibility in achieving net zero \(A\)](#). It excludes domestic demand side response.
- 89 Commission analysis of Aurora Energy Research (2023), [The role of system flexibility in achieving net zero \(A\)](#)
- 90 Department for Energy Security and Net Zero (2022), [Review of Electricity Market Arrangements](#)
- 91 Regen (2023), [Improving locational signals in the GB electricity markets](#)
- 92 Department for Energy Security and Net Zero (2023), [Powering Up Britain: Energy Security Plan](#)
- 93 Commission analysis of Aurora Energy Research (2023), [The role of system flexibility in achieving net zero \(A\)](#). Analysis shows that a system with very high levels of consumer flexibility would be roughly £5 billion a year cheaper in 2035 than a system with no additional demand side flexibility added beyond 2025.
- 94 National Infrastructure Commission (2015), [Smart Power](#)
- 95 Commission analysis of Aurora Energy Research (2023), [The role of system flexibility in achieving net zero \(A\)](#). 30TWh of generation to manage the longest shortfalls would require at least 12GW of capacity.
- 96 Department for Energy Security and Net Zero (2023), [The future policy framework for the delivery of power with carbon capture, usage and storage: government response](#); Department for Energy Security and Net Zero (2021), [UK Hydrogen Strategy](#)
- 97 Department for Energy Security and Net Zero (2022), [Carbon capture usage and storage: Dispatchable Power Agreement business model](#)
- 98 SSE (2021), [Plans for first of a kind hydrogen and CCS projects](#); Siemens Energy, [Hydrogen power plants](#)
- 99 Department for Energy Security and Net Zero (2023), [Digest of UK Energy Statistics, Table 5.11 for 2005](#)
- 100 Commission analysis of Aurora Energy Research (2023), [The role of system flexibility in achieving net zero \(A\)](#)
- 101 The Royal Society (2023), [Large Scale Electricity Storage](#)
- 102 Department for Energy Security and Net Zero (2021), [UK Hydrogen Strategy](#)
- 103 Williams et al. (2022), [Does the United Kingdom have sufficient geological storage capacity to support a hydrogen economy? Estimating the salt cavern storage potential of bedded halite formations](#)
- 104 Hydrogen UK (2022), [Hydrogen Storage: Delivering on the UK's Energy Needs](#)
- 105 Aurora Energy Research (2023), [The impact of decarbonising heating in the power sector \(C\)](#)
- 106 Department for Energy Security and Net Zero (2023), [Digest of UK Energy Statistics](#)
- 107 Department for Energy Security and Net Zero (2023), [Decarbonisation readiness: updates to the 2009 Carbon Capture Readiness requirements](#)
- 108 National Infrastructure Commission (2023), [Delivering net zero, climate resilience and growth: Improving nationally significant infrastructure projects](#)
- 109 National Infrastructure Commission (2023), [Delivering net zero, climate resilience and growth: Improving nationally significant infrastructure projects](#)
- 110 Ofgem (2022), [Decision on accelerating onshore electricity transmission investment](#)
- 111 Department for Energy Security and Net Zero (2023), [Energy Security Bill Factsheet: Ofgem net zero duty](#); Department for Energy Security and Net Zero (2023), [Strategy and Policy Statement for energy policy in Great Britain](#)
- 112 Department for Energy Security and Net Zero (2023), [Independent report: Accelerating electricity transmission network deployment: Electricity Networks Commissioner's recommendations](#)
- 113 National Grid ESO (2022), [The Pathway to 2030 Holistic Network Design](#); Ofgem (2022), [Decision on the initial findings of our Electricity Transmission Network Planning review](#)
- 114 Ofgem (2022), [RIIO-ED2 Final Determinations](#)
- 115 Ofgem (2023), [Consultation: Future of local energy institutions and governance](#)
- 116 Energy Systems Catapult (2023), [Local Area Energy Planning](#)

- 117 Regen (2023), [Building a GB electricity network ready for net zero](#)
- 118 Office for Budget Responsibility (2023), [Economic and fiscal outlook March 2023](#)
- 119 Office for Budget Responsibility (2022), [The changing impact of fossil fuel shocks on the UK economy](#)
- 120 As a member of the International Energy Agency (IEA) the UK hold stocks of oil so that collectively IEA members can respond to international oil disruption, International Energy Agency (2023), [Oil Stocks of IEA Countries](#); there are capital requirements on UK banks, Bank of England (2023), [The Financial Policy Committee's approach to setting the countercyclical capital buffer](#)
- 121 The choice of 61 days is based on the requirements of the EU Oil Stocks Directive for net exporters of oil, European Commission (2023), [EU oil stocks](#)
- 122 National Infrastructure Commission (2020), [Anticipate, React, Recover: Resilient infrastructure systems](#)
- 123 Hydrogen UK (2022), [Hydrogen Storage: Delivering on the UK's Energy Needs](#)
- 124 Department for Energy Security and Net Zero (2023), [Digest of UK Energy Statistics](#)
- 125 Department for Levelling Up, Housing and Communities (2022), [English Housing Survey Energy Report, 2020-21](#)
- 126 Commission analysis based on Aurora Energy Research (2023), [Decarbonising heating systems: evidence and options \(B\)](#). This figure includes switches to all forms of low carbon heating including heat pumps, heat networks and electric resistive heating.
- 127 Department for Levelling Up, Housing and Communities (2022), [English Housing Survey Energy Report, 2020-21](#)
- 128 The Commission's remit extends to economic infrastructure within the UK government's competence. For policy related to heating and energy efficiency there is substantial devolution to Northern Ireland, Scotland and Wales.
- 129 Department for Energy Security and Net Zero (2023), [Carbon Budget Delivery Plan](#)
- 130 Thinks Insight & Strategy (2023), [Social research for the National Infrastructure Commission to inform the second National Infrastructure Assessment](#)
- 131 Williams (1981), A History of the British Gas Industry
- 132 Nesta, [The rise of indoor plumbing in the UK: lessons for the green transition](#)
- 133 Thinks Insight & Strategy (2023), [Social research for the National Infrastructure Commission to inform the second National Infrastructure Assessment](#); UK Collaborative Centre for Housing Evidence (2023), [Motivations and Barriers Associated with Adopting Domestic Heat Pumps in the UK](#)
- 134 Department for Energy Security and Net Zero (2023), [Energy Security Bill factsheet: Low-carbon heat scheme](#)
- 135 LCP Delta for Energy Systems Catapult (2022), [BEIS Electrification of Heat Demonstration Project: Home Surveys and Install Report](#)
- 136 House of Lords Environment and Climate Change Committee (2023), [Boiler upgrade scheme inquiry: Written evidence from the Department for Business, Energy and Industrial Strategy \(BEIS\)](#)
- 137 Department for Levelling Up, Housing and Communities (2022), [English Housing Survey 2021 to 2022: headline report, annex tables](#)
- 138 Energy Systems Catapult (2023), [Heat pumps shown to be three times more efficient than gas boilers](#)
- 139 Department for Levelling Up, Housing and Communities (2022), [English housing survey headline report. Section 2: housing stock annex tables](#). Space constrained is defined as an indoor floor space of less than 50m²
- 140 Energy Savings Trust (2023), [Thermal energy stores](#)
- 141 Element Energy (2019), [Evidence gathering for electric heating options in off gas grid homes: final report](#)
- 142 HM Treasury (2022), [Autumn Statement 2022](#)
- 143 BRE (2023), [The cost of poor housing in England by tenure](#)
- 144 Social housing has a particularly high proportion of lone parent households (18 per cent) and households with at least one member with a long-term illness or disability (54 per cent), see Department for Levelling Up, Housing and Communities (2023), [English Housing Survey 2021 to 2022: social rented sector](#). Disabled people are twice as likely to live in poverty as non-disabled people, see ClimateJust (2023), [Who is affected by fuel poverty?](#)

- 145 HM Government (2023), [Help from your energy supplier: the Energy Company Obligation](#)
- 146 Department for Energy Security and Net Zero (2023), [Social Housing Decarbonisation Fund](#)
- 147 Department for Energy Security and Net Zero (2023), [Domestic private rented property: minimum energy efficiency standards – landlord guidance](#)
- 148 HM Government (2021), [Heat and Buildings Strategy](#)
- 149 Commission analysis of Department for Energy Security and Net Zero (2023), [Home Upgrade Grant: Phase 2 Delivery Guidance for Local Authorities](#)
- 150 Energy Systems Catapult (2021), [Policy Brief: Skills for net zero homes](#)
- 151 Climate Change Committee (2023), [A Net Zero workforce](#)
- 152 Commission analysis of switching levels needed to meet emissions limits set out in Department for Energy Security and Net Zero (2023), [Carbon Budget Delivery Plan](#)
- 153 Climate Change Committee (2023), [2023 Progress Report to Parliament – Supplementary indicator data](#)
- 154 Commission analysis of European Heat Pump Association (2022), European Heat Pump Market and Statistics Report 2022
- 155 International Energy Agency (2020), [The Netherlands 2020: Energy Policy Review](#); Netherlands Enterprise Agency (2023), [Heat pumps mandatory when replacing a boiler](#)
- 156 International Energy Agency (2023), [Policies database for France](#)
- 157 International Energy Agency (2023), [Policies database for Poland](#)
- 158 A heat pump is assumed to cost on average £13,000, Department for Energy Security and Net Zero (2023), [Boiler Upgrade Scheme Statistics: June 2023](#); and a gas boiler is assumed to cost on average £3,000, Aurora Energy Research (2023), [Decarbonising heating systems: evidence and options \(B\)](#)
- 159 Thinkinsight & Strategy (2023), [Social research for the National Infrastructure Commission to inform the second National Infrastructure Assessment](#); Nesta (2021), [Decarbonising homes: Consumer attitudes towards energy efficiency and green heating in the UK](#)
- 160 Nesta (2023), [All the things I could do: financing green home upgrades](#)
- 161 Department for Energy Security and Net Zero (2023), [Annual Domestic Energy Bills, Table 2.2.4 and 2.3.4](#)
- 162 Social tariffs are a feature of charging for other utilities: Department for Environment, Food & Rural Affairs (2012), [Company Social Tariffs: Guidance to water and sewerage undertakers and the Water Services Regulation authority](#); Ofcom (2023), [Social tariffs: Cheaper broadband and phone packages](#)
- 163 Department for Energy Security and Net Zero (2023), [Clean Heat Market Mechanism](#)
- 164 Prime Minister's Office (2023), [PM recommits UK to Net Zero by 2050 and pledges a "fairer" path to achieving target to ease the financial burden on British families](#)
- 165 Department for Energy Security and Net Zero (2023), [Boiler Upgrade Scheme Regulations: Consultation](#)
- 166 HM Government (2015), [The Town and Country Planning \(General Permitted Development\) \(England\) Order 2015](#)
- 167 House of Commons Business Energy and Industrial Strategy Committee (2022), [Decarbonising heat in homes](#)
- 168 Competitions & Markets Authority (2023), [Consumer protection in the green heating and insulation sector](#)
- 169 Department for Energy Security and Net Zero (2023), [Green Heat Network Fund \(GHNF\): guidance on how to apply](#)
- 170 HM Government (2021), [Heat and Buildings Strategy](#)
- 171 HM Government (2021), [UK Hydrogen Strategy](#)
- 172 National Infrastructure Commission (2023), [Technical Annex: Hydrogen Heating](#)
- 173 Leti (2021), [Is Hydrogen a decarbonisation route for heat in buildings?](#); Hydrogen Science Coalition (2022), [Hydrogen for Heating? A comparison the heat pumps \(Part 1\)](#)
- 174 National Infrastructure Commission (2023), [Technical Annex: Hydrogen Heating](#)
- 175 Office for National Statistics (2023), [LFS: Economic inactivity rate](#). The economic inactivity rate for working age adults has steadily fallen since the 1970s.

- 176 Arup and Department for Business, Energy and Industrial Strategy (2022), [Hy4heat Report: Final Progress Report](#); Lewis (2021), [Optimising air quality co-benefits in a hydrogen economy: a case for hydrogen-specific standards for NOx emissions](#), Environmental Science: Atmospheres, 5
- 177 Citizens Advice (2020), [Taking the temperature: Consumer choice and low carbon heating](#)
- 178 The planned Future Homes Standard and Future Buildings Standards may be the route to deliver this. Ministry of Housing, Communities & Local Government (2021), [The Future Homes Standard: changes to Part L and Part F of the Building Regulations for new dwellings](#)
- 179 Commission analysis of Aurora Energy Research (2023), [Decarbonising heating systems: evidence and options \(B\)](#)
- 180 Commission analysis of Department for Energy Security and Net Zero (2023), [Final UK greenhouse gas emissions national statistics: 1990 to 2021](#)
- 181 Prime Minister's Office (2023), [PM recommits UK to Net Zero by 2050 and pledges a "fairer" path to achieving target to ease the financial burden on British families](#)
- 182 The average lifetime of a fossil fuel boiler is assumed to be 15 years. Aurora Energy Research (2023), [Decarbonising heating systems: evidence and options \(B\)](#)
- 183 HM Government (2020), [The Ten Point Plan for a Green Industrial Revolution](#)
- 184 Department for Environment, Food & Rural Affairs (2021), [Greening Government Commitments 2021 to 2025](#)
- 185 Department for Transport (2023), [A zero emission vehicle \(ZEV\) mandate and CO2 emissions regulation for new cars and vans in the UK](#)
- 186 Department for Transport and Office for Zero Emission Vehicles (2023), [Transitioning to zero emission cars and vans: 2035 delivery plan](#)
- 187 Office for Budget Responsibility (2021), [Fiscal risks report; Frazer-Nash Consultancy \(2018\), Logistics of Domestic Hydrogen Production](#)
- 188 Williams (1981), A History of the British Gas Industry
- 189 Arup (2023), [Future of GB Gas Networks Assessment](#)
- 190 Ofgem (2023), [Consultation: Future of local energy institutions and governance](#)
- 191 Commission analysis of Department for Energy Security and Net Zero (2023), [Digest of UK Energy Statistics](#)
- 192 Climate Change Committee (2023), [2023 Progress Report to Parliament – Charts and data](#)
- 193 Commission analysis of Department for Transport (2021), [Decarbonising transport: a better, greener Britain](#); Department for Transport (2021), [Additional information on assumptions used to develop decarbonising transport scenarios](#)
- 194 Ofgem (2018), [Implications of the transition to electric vehicles](#); Department for Transport (2021), [Decarbonising transport: a better, greener Britain](#); Local Government Association (2023), [The case for electric vehicles](#); House of Commons Library (2023), [Electric vehicles and infrastructure](#); European Environment Agency (2018), [Electric vehicles from life cycle and circular economy perspectives](#)
- 195 Climate Change Committee (2023), [2023 Progress Report to Parliament](#); Zapmap (2023), [Zapmap Price Index](#); Commission analysis of Department for Transport (2022), [Transport Analysis Guidance](#)
- 196 European Federation for Transport and Environment and BloombergNEF (2021), [Hitting the EV inflection point](#)
- 197 HM Government (2022), [Taking charge: the electric vehicle infrastructure strategy](#)
- 198 HM Government (2022), [Taking charge: the electric vehicle infrastructure strategy](#)
- 199 Department for Transport (2023), [Monthly total number of electric vehicle public charging devices available in the UK, 1 August 2023](#)
- 200 Department for Transport (2023), [Monthly total number of electric vehicle public charging devices available in the UK, 1 August 2023](#)
- 201 HM Government (2023), [Powering Up Britain: The Net Zero Growth Plan](#); HM Government (2022), [Taking charge: the electric vehicle infrastructure strategy](#)
- 202 International Energy Agency (2023), [Global EV Outlook 2023](#)

- 203 Ofgem (2022), [Access and Forward-Looking Charges Significant Code Review: Final Decision](#)
- 204 HM Government (2022), [Taking charge: the electric vehicle infrastructure strategy](#)
- 205 Perceived lack of charging infrastructure and uneven regional distribution of the UK's electric vehicle charging infrastructure is often found to be a barrier to electric vehicle take up. Department for Transport (2022), [Public Electric Vehicle Charging Infrastructure](#); Competition & Markets Authority (2021), [Electric vehicle charging market study: final report](#)
- 206 HM Government (2022), [Taking charge: the electric vehicle infrastructure strategy](#)
- 207 Geospatial Commission (2023), [Charging Ahead: Using location data to boost local EV charge point rollout](#)
- 208 Department for Transport (2023), [Zero emission vehicle \(ZEV\) mandate consultation: summary of responses and joint government response](#)
- 209 Department for Transport (2023), [Zero emission vehicle \(ZEV\) mandate consultation: summary of responses and joint government response](#)
- 210 Department for Transport (2023), [Consultation on a zero emission vehicle \(ZEV\) mandate and CO2 emissions regulation for new cars and vans in the UK](#)
- 211 Climate Change Committee (2023), [2023 Progress Report to Parliament](#)
- 212 Commission analysis of Department for Transport (2021), [Decarbonising transport: a better, greener Britain](#); Department for Transport (2021), [Additional information on assumptions used to develop decarbonising transport scenarios](#)
- 213 HM Government (2023), [Carbon Budget Delivery Plan](#)
- 214 Royal Courts of Justice (2022), [Friends of the Earth -v- BEIS judgment](#)
- 215 Department for Energy Security and Net Zero (2023), [Digest of UK Energy Statistics](#)
- 216 Department for Energy Security and Net Zero (2023), [Carbon Budget Delivery Plan](#)
- 217 Climate Change Committee (2020), [Sixth Carbon Budget](#)
- 218 HM Government (2020), [The Ten Point Plan for a Green Industrial Revolution](#)
- 219 Department for Energy Security and Net Zero (2023), [Hydrogen transport and storage infrastructure: minded to positions](#)
- 220 For example, a transmission network would need to make hydrogen roughly five to ten per cent cheaper to offset the cost of creating the connected network.
- 221 Hydrogen made through electrolysis can require nine litres of water to produce 1kg of hydrogen with additional water required for processing such as cooling, Ramirez et al (2023), [Hydrogen Reality Check: Distilling Green Hydrogen's Water Consumption](#)
- 222 Department for Energy Security and Net Zero (2021), [Consents and planning applications for national energy infrastructure projects](#)
- 223 Competition will also need to be factored into development expenditure allocations. The current gas network price controls include reopeners allowing for some development expenditure to be recovered through gas bills, but this mechanism alone cannot allow fully competitive allocations.
- 224 The Royal Society (2022), [Locked away – geological carbon storage: Policy briefing: the Royal Society](#)
- 225 Arup (2023), [Future of GB Gas Networks Assessment](#). Reuse is estimated to reduce capital costs by 75 per cent.
- 226 Global CCS Institute (2022), [Understanding CCS: Transport](#)
- 227 National Infrastructure Commission (2021), [Engineered greenhouse gas removals](#)
- 228 National Atmospheric Emissions Inventory (2020), [Emissions from NAEI large point sources](#)
- 229 Commission analysis of National Atmospheric Emissions Inventory (2020), [Emissions from NAEI large point sources](#)

3. Growth across all regions

- 230 Centre for Cities (2020), [Why big cities are crucial to ‘levelling up’](#)
- 231 Department for Transport (2023), [Domestic Transport Usage by Mode](#); Department for Transport (2023), [Light rail and tram statistics, England: year ending March 2023](#)
- 232 Manchester City Council (2023), [Economy and Regeneration Scrutiny Committee, Public Document Pack](#)
- 233 Greater Manchester Combined Authority (2023), [GMCA Transport Revenue Budget 2023/24](#); Department for Transport (2023), [Annual bus statistics: year ending March 2022 \(revised\)](#); Greater Manchester Combined Authority (2023), [GMCA Transport Revenue Budget 2023/24](#)
- 234 Steer (2022), [Continuing COVID Funding Support for Urban Public Transport](#); Department for Transport (2023), [Annual bus statistics: year ending March 2022 \(revised\)](#)
- 235 This is a concern that stakeholders in large cities have raised with the Commission. The West Midlands Combined Authority, for example, has recently re-allocated £40 million of Bus Service Improvement Plan money to sustain existing services, reflecting increasing costs and decreasing revenues. Given this is one-off funding it implies the potential for an ongoing funding gap, as well as a reduced scope for service enhancement to help attract more users. West Midlands Combined Authority (2023), [Bus network protected until 2025 following £40 million investment from TfWM](#)
- 236 Steer (2022), [Continuing COVID Funding Support for Urban Public Transport](#)
- 237 National Infrastructure Commission (2021), [Behaviour change and infrastructure beyond Covid-19](#)
- 238 House of Lords Library (2020), [Coronavirus: Support for the transport sector](#); Department for Transport (2022), [Local transport update: financial support for bus and light rail services](#)
- 239 Urban Transport Group (2023), [Survive or thrive - Has Government watered down its ambition to truly transform bus services?](#)
- 240 D Puga (2009), [The magnitude and causes of agglomeration economies](#)
- 241 Centre for Cities (2021), [Measuring Up](#); Stansbury, Turner & Balls (2023), [Tackling the UK’s regional economic inequality: Binding constraints and avenues for policy intervention](#)
- 242 Centre for Cities (2021), [Measuring Up](#); Stansbury, Turner & Balls (2023), [Tackling the UK’s regional economic inequality: Binding constraints and avenues for policy intervention](#)
- 243 Centre for Cities (2020), [Why big cities are crucial to ‘levelling up’](#)
- 244 Resolution Foundation (2023), [A tale of two cities \(part 1\)](#); Resolution Foundation (2023), [A tale of two cities \(part 2\)](#)
- 245 Centre for Cities (2021), [Measuring Up](#)
- 246 Centre for Cities (2021), [Measuring Up](#)
- 247 Coyle & Sensier (2018), [The Imperial Treasury: appraisal methodology and regional economic performance in the UK](#); see Table 1; González-Pampillón & Overman (2020), [Regional differences in UK transport BCRs: an empirical assessment](#). These show estimated benefit cost ratios of around two for local and urban transport schemes outside of London. Under the Department for Transport’s [value for money framework](#) many of these would be categorised as ‘high’ value for money. In addition, if face to face interaction is less important for productivity, and working from home increases further on today’s levels, then the returns to investment would be lower. In this case you would not expect to see commuter demand growing much from today’s levels, in which case it may make sense to adopt more modest options for urban transport than the maximum level of ambition indicated here – hence the need for an adaptive approach. On the other hand, if demand for congested urban space does grow in line with the Commission’s mid-range scenarios, it is likely that this indicates that employers do continue to value face to face interaction, such that high returns should be expected on urban transport investment; National Infrastructure Commission (2019), [Capturing the value of urban transport investments](#); see table on page 11
- 248 Steer (2023), [Urban Transport Capacity, Demand and Cost: Main Report](#)
- 249 Steer (2023), [Urban Transport Capacity, Demand and Cost: Research Methodology](#)

- 250 Office for National Statistics (2023), [UK gross value added \(GVA\) and productivity estimates for other geographies](#)
- 251 A full version of this chart, which shows the results of the analysis for other cities, can be found in Steer (2023), [Urban Transport Capacity, Demand and Cost: Research Methodology](#)
- 252 The 15 largest cities have been selected on the basis of the population of Primary Urban Areas, which measures the ‘built-up’ area of a city rather than individual local authorities. Northampton is in the top 15 Primary Urban Areas by population, but as the Primary Urban Area for Northampton includes all of West Northamptonshire, Northampton has been excluded from this table. Centre for Cities (2022), [2022 Primary Urban Areas Table](#)
- 253 Department for Transport (2019), [Light Rail \(and other rapid transit solutions\)](#); Steer (2023), [Urban Transport Capacity, Demand and Cost: Main Report](#)
- 254 National Infrastructure Commission (2022), [Managing uncertainty in the second National Infrastructure Assessment](#)
- 255 Steer (2023), [Urban Transport Capacity, Demand and Cost: Research Methodology](#). Please see Table 3.6 for further details on all eight scenarios.
- 256 Centre for Cities (2021), [Measuring Up](#)
- 257 Urban Transport Group (2018), [Bus Rapid Transit](#)
- 258 West Yorkshire Combined Authority (2022), [West Yorkshire Mass Transit Vision 2040](#)
- 259 Transport for Greater Manchester (2023), [Say yellow to the Bee Network](#)
- 260 Despite their mass transit networks, the main mode of travel for commuters in the wider city regions of Liverpool, Sheffield and Manchester is the car; see Liverpool City Region (2022), [Developing a vision for local transport to 2040](#); Cycle Sheffield (2022), [Modes of transport used in Sheffield](#) and Deloitte (2022), [Deloitte City Mobility Index 2020](#)
- 261 Steer (2023), [Urban Transport Capacity and Demand Analysis: Demand Management Report](#)
- 262 Leeds City Council (2021), [Connecting Leeds Transport Strategy](#)
- 263 Britain Thinks (2020), [Road congestion deliberative research](#)
- 264 Steer (2023), [Urban Transport Capacity and Demand Analysis: Demand Management Report](#)
- 265 HM Treasury analysis of National Travel Survey data, based on three years of data between 2016 and 2018. Department for Work and Pensions (2022), Ethnicity facts and figures – income distribution. Presents percentage of households in each income quintile by ethnicity, before and after housing costs. Data shows that certain ethnic groups have disproportionately more households in lower income groups and fewer in higher income groups (Black, Pakistani, Bangladeshi, Other). Some ethnic groups have similar proportions of households in each income group (White, White British, Indian, Chinese).
- 266 Institute for Public Policy Research (2023), [State of the North 2023](#); House of Commons Library (2018), [Transport Spending by Region](#); Institute for Public Policy Research (2019), [North set to receive £2,389 less per person than London on transport](#)
- 267 Institute for Government (2022), [Subnational government in England](#)
- 268 London Finance Commission (2016), [International Comparison of Global City Financing](#)
- 269 Resolution Foundation (2022), [Centralisation Nation](#)
- 270 Resolution Foundation (2022), [Centralisation Nation](#)
- 271 House of Commons Library (2023), [Local government taxation](#)
- 272 The UK Infrastructure Bank confirmed this in discussion with the Commission
- 273 United Kingdom Debt Management Office, [PWLB lending facility](#)
- 274 UK Infrastructure Bank (2022), [Strategic Plan](#)
- 275 These difficulties were shared with the Commission at a private roundtable discussion on funding and financing
- 276 Nottingham City Council, [Workplace Parking Levy](#)

- 277 Nottingham City Council (2022) [Councillor Rosemary Healy, Nottingham City Council's Portfolio Holder for Transport, takes a look back on ten years of the Workplace Parking Levy](#)
- 278 Department for Transport (2011), [Construction of Nottingham tram extensions to start](#); Nottingham City Council (2011), [Nottingham Express Transit \(NET\) Phase Two Procurement](#)
- 279 Department for Transport (2021), [City Region Sustainable Transport Settlements: guidance for mayoral combined authorities](#); [City Region Sustainable Transport Settlements: confirmed allocations](#)
- 280 National Infrastructure Commission (2019), [National Infrastructure Assessment](#)
- 281 National Infrastructure Commission (2021), [Infrastructure, Towns and Regeneration](#)
- 282 Department for Levelling Up, Housing and Communities (2022), [Levelling Up White Paper](#)
- 283 HM Treasury (2023), [Spring Budget 2023](#)
- 284 Office for National Statistics (2021), [Country and regional public sector finances: financial year ending 2020](#)
- 285 Transport for London (2021), [Draft TfL 2021 Long-Term Capital Plan \(LTCP\)](#)
- 286 Transport for London (2023), [Public Transport Journeys by Type of Transport](#)
- 287 Transport for London (2023), [Annual budget for 2023/24 shows TfL set to deliver operating surplus](#)
- 288 Institution of Civil Engineers (2017), [Crossrail project: finance, funding and value capture for London's Elizabeth line](#)
- 289 Transport for London (2022), [Draft TfL Mayor's Budget 2023/24](#)
- 290 Department for Transport (2020), [National Travel survey \(2019\), Commission's analysis](#)
- 291 Department for Transport (2022), [Annual Road Traffic estimates 2021](#); Office of Rail and Road (2023), [Table 1343 – Freight vehicle kilometres by operator](#)
- 292 Department for Transport (2023), [National Statistics Provisional road traffic estimates, Great Britain: July 2022 to June 2023](#)
- 293 Office of Rail and Road (2023), [Table 1223 – Passenger journeys by operator](#). The opening of the Elizabeth Line may also have impacted rail usage statistics in two ways. Firstly, the new rail line will have had an impact of moving journeys to the rail statistics that would otherwise have been made by modes of transport – for example, on the London Underground – which are not recorded in the LENNON rail database that is used by the ORR to calculate rail usage statistics. This makes comparing usage before and after opening of the Elizabeth Line difficult. Secondly, there is a technical issue with the ORR's data which has resulted in an overestimation of Elizabeth Line journeys. We have therefore excluded Elizabeth Line statistics from this comparison.
- 294 Highways England (2017), [Highways England Strategic Road Network Initial Report](#)
- 295 Department for Transport (2006), [The Eddington Transport Study](#)
- 296 House of Commons Library (2019), [Local roads maintenance in England](#); Department for Transport (2022), [Road conditions in England to March 2022](#)
- 297 Frontier Economics (2017), [Exploring the economic benefits of strategic roads. Report produced for Department for Transport](#); Laird and Johnson (2021), [The GDP Effects of Transport Investments: The Macroeconomic Approach](#). There is wide ranging literature on the topic of transport and economic performance. For example, the Frontier Economics report sets out the theoretical mechanisms on how transport investment improves economic performance, including trade and how benefits to key users (freight and business travellers) also affect economic performance. The Laird and Johnson report explains that the key mechanism for interurban (long distance trips that tend to be between cities or regions) is around trade, particularly the location of firms that depend on market access and transport costs between regions.
- 298 National Audit Office (2022), [Road enhancements: progress with the second road investment strategy \(2020 to 2025\)](#)
- 299 National Highways (2023), [Our Route Strategies](#)
- 300 See for example Transport for the North (2019), [Strategic Transport Plan](#)
- 301 Department for Transport (2021), [Planning ahead for the Strategic Road Network](#)

- 302 Laird & Johnson (2021), [The GDP Effects of Transport Investments: The Macroeconomic Approach](#); Melo et al (2013), [The Productivity of Transport Infrastructure Investment: A Meta-Analysis of Empirical Evidence](#)
- 303 National Infrastructure Commission (2019), [Transport Connectivity, Discussion paper](#)
- 304 Department for Transport (2022), [Transport and environment statistics 2022](#); Department for Transport (2020), [National Travel Survey: 2019](#); Commission analysis of survey data
- 305 Department for Transport (2023), [Assumed levels of road traffic and percentage of road traffic from zero emission vehicles, in decarbonising transport upper and lower bound scenarios](#)
- 306 The 2018 [Department for Transport literature review](#) found that road enhancements may increase national traffic volumes by around 0.2 per cent for each one percent increase in capacity; more recent estimates ([Transport for Quality of Life 2020](#)) find a two per cent year on year growth specifically on the improved road corridors. Capacity increases on the Strategic Road Network as a result of road building in 2017-20 amounted to approximately 0.4 per cent per annum (ORR (2017-21), [Annual Assessments of National Highways/Highways England 2017-2021](#)). Our upper end estimate is calculated on a doubling of the year on year growth rate to 4 per cent for improved parts of the network.
- 307 National Infrastructure Commission (2020), [Rail Needs Assessment](#)
- 308 Office of Rail and Road (2023), [Passenger Rail Performance 1 April to 30 June 2023](#)
- 310 Department for Transport (2021), [Integrated Rail Plan for the North and Midlands](#)
- 310 National Infrastructure Commission (2020), [Rail Needs Assessment for the Midlands and the north, Modelling and Data Annex](#). Please see Table 5.1 in the Annex, productivity and amenity benefits are based on the regional links plus 25 per cent package.
- 311 Centre for Cities (2016), Building the Northern Powerhouse
- 312 European Commission (2016), Working paper: Towards regional and urban indicators on rail passenger services, using timetable information (Map 2)
- 313 Department for Transport (2023), [Network North Transforming British Transport](#)
- 314 National Infrastructure Commission (2016), [Partnering for Prosperity: A new deal for the Cambridge-Milton Keynes-Oxford Arc](#)
- 315 The Integrated Rail Plan included proposals to electrify and/or upgrade the Transpennine Route, Midlands Main Line and East Coast Mainline
- 316 Pantelis Koutroumpis (2018), [The economic impact of broadband: evidence from OECD countries](#). Other studies have found strong links between broadband rollout and economic growth. The rollout of broadband infrastructure in OECD countries from 1997 to 2007 increased per capita growth by 0.9 to 1.5 percentage points for a ten percentage point increase in broadband penetration; see Czernick et al (2011), Broadband Infrastructure and Economic Growth, Economic Journal
- 317 Ofcom (2018), [Connected Nations Update: October 2018](#). Figure is for full fibre coverage as Ofcom did not report separately on gigabit capable coverage in 2018. Figure is for May 2018.
- 318 Department for Digital, Culture, Media and Sport (2018), [Future Telecoms Infrastructure Review](#)
- 319 Ofcom (2023), [Connected Nations Summer 2023 update: Interactive report](#). Coverage figures are for May 2023 and are for all premise types (residential and commercial).
- 320 Ofcom (2023), [Connected Nations Summer 2023 update: Interactive report](#). Coverage figures are for May 2023
- 321 Ofcom (2021), [Wholesale Fixed Telecoms Market Review 2021-26](#), which sets out a series of decisions designed to support investment in gigabit capable networks, including policies to allow pricing flexibility and promote competition between networks, where viable. The government has also continued to remove barriers to deploying new gigabit capable networks. [The Product Security and Telecommunications Infrastructure Act](#) received Royal Assent in December 2022. This made changes to the Electronic Communications Code to make it easier for operators to reach agreements to access private land to deploy telecoms infrastructure. It also strengthened the rights of operators to upgrade and share existing apparatus to deploy new networks.
- 322 Openreach (2023), [Press release: We've reached our first 10 million homes and businesses with ultrafast, ultra-reliable Full Fibre broadband](#)
- 323 The Independent Networks Cooperative Association (2023), [Metrics for the UK independent network sector](#)

- 324 'Nationwide' gigabit coverage by 2030 is defined as at least 99 per cent of premises in HM Government (2022), [Levelling Up The United Kingdom](#)
- 325 Ofcom (2022), [Connected Nations 2022](#)
- 326 Ofcom (2023), [Connected Nations Summer 2023 update: Interactive report](#); coverage figures are for April 2023
- 327 Ofcom (2023), [Connected Nations Summer 2023 update: Interactive report](#); coverage figures are for April 2023
- 328 Department for Digital, Culture, Media & Sport (2020), [Shared Rural Network press release](#)
- 329 Department for Science, Innovation & Technology (2023), [UK Wireless infrastructure Strategy](#)
- 330 Ofcom (2019), [Mobile signal strength measurement data from Network Rail's engineering trains](#)
- 331 Department for Science, Innovation & Technology (2023), [UK Wireless infrastructure Strategy](#)
- 332 The ultrareliable, low latency, high speed and high capacity networks are features of 5G standalone networks. Most existing 5G networks in the UK are currently non standalone, although standalone 5G deployment in the UK has begun in 2023; see Vodafone (2023), [Vodafone launches 5G Ultra, the UK's first 5G standalone mobile network for consumers](#)
- 333 GSMA (2023), [Securing the 5G Era](#)
- 334 Ofcom (2023), [Connected Nations Summer 2023 update: Interactive report](#). Figure is for April 2023, and is for the percentage of UK premises that can get 'very high confidence' of 5G coverage from at least one operator to the outside of the premises. Twelve per cent of UK premises could get very high confidence of 5G coverage from all four operators. Eighty five per cent of premises had 'high confidence' of 5G coverage from at least one mobile network operator to the outside of the premises, and 22 per cent had high confidence of 5G coverage from all four operators.
- 335 Vodafone (2023), [Vodafone launches 5G Ultra, the UK's first 5G standalone mobile network for consumers](#)
- 336 Analysys Mason (2023), [5G wireless infrastructure deployment scenarios over the next decade](#), Figure 1.1. The estimated cost for the wide area public network in scenario 1 and 2 is £8.872 billion and in scenario 3 is £8.907 billion.
- 337 Frontier Economics (2022), [The investment gap to full 5G rollout](#)
- 338 O2 plans to reach 50 per cent 5G population coverage by the end of 2023, (O2 (2023), [All you need to know about our network expansion plans](#)), and BT EE has announced its intention to reach 90 per cent 5G geographic coverage by 2028 (EE (2021), [EE to offer 5G solutions across the entire UK](#)). In June 2023, the two smallest Mobile Network Operators, Vodafone and Three, announced plans to merge. They claim that, as a result of the merger, there would be an additional £11 billion investment in 5G networks over the next ten years, and they would be able to reach 95 per cent standalone coverage by 2030 (Vodafone and Three (2023), [Building the UK's Digital Future](#)). The merger is subject to approval by the Competition and Markets Authority, and any decision on this is unlikely to be made for several years.
- 339 Department for Science, Innovation & Technology (2023), [UK Wireless infrastructure Strategy](#)
- 340 Mobile UK, (2022), [Building Mobile Britain: the case for local authority digital champions](#)
- 341 As of August 2023, there were 591 companies that held low and medium power Shared Access Licences in the 3.8 to 4.2 GHz spectrum bands; see Ofcom (2023), [Spectrum information portal](#) (interactive portal accessed 30/08/23)
- 342 Shared access licences are available in the 1800 MHz band, the 2300 MHz band, the 3800 to 4200 MHz band and (for indoor low power licences only) the 24.25 to 26.5 GHz band. Most 5G networks use the 3800 to 4200 MHz band.
- 343 Ofcom (2023), [Evolution of the Shared Access Licence Framework: Call for Input](#)
- 344 Analysys Mason (2023), [5G wireless infrastructure deployment scenarios over the next decade](#)
- 345 Ofcom (2023), [Call for Input: Potential spectrum bands to support utilities sector transformation](#)
- 346 International Union of Railways (2023), [Future Railway Mobile Communication System: Use cases](#), version 2.1.0

4. Improving resilience and the environment

- 347 Climate Change Committee (2022), Understanding Climate Risks to UK Infrastructure: Evaluation of the Third Round of the Adaptation Reporting Power – July 2022
- 348 House of Commons Library (2023), Gas and Electricity Prices under the Energy Price Guarantee and Beyond
- 349 National Infrastructure Commission (2018), Preparing for a Drier Future
- 350 State of Nature Partnership (2023), State of Nature 2023
- 351 Environment Agency (2023), Reflections on Water: The good, the bad and the future
- 352 Environment Agency (2023), Water and Sewerage Companies in England: Environmental performance report 2022; HM Government (2021), 25 Year Environment Plan Annual Progress Report, April 2020 to March 2021
- 353 HM Government (2018), Our waste, our resources: A strategy for England; Department for Environment, Food and Rural Affairs (2019), Consistent Municipal Recycling Collections in England Impact Assessment
- 354 Ofgem (2016), Know Your Rights: Power cuts. Different recently revised standards now apply to extreme events. See Ofgem (2023), Ofgem announces rise in storm compensation cap from £700 to £2000
- 355 National Infrastructure Commission (2023), Letter from James Heath to David Black
- 356 HM Government (2022), The UK Government Resilience Framework
- 357 Network Rail (2023), England and Wales Strategic Business Plan. Control Period 7
- 358 Ofwat (2022), Creating Tomorrow, Together: Our Final Methodology for PR24
- 359 Thames Water (2023), Annual Performance Report
- 360 Professor David Balmforth (2020), Toddbrook Reservoir Independent Review Report
- 361 UK Climate Risk (2021), UK Climate Risk Independent Assessment (CCRA3), Technical Report Chapter 4: Infrastructure
- 362 UK Climate Risk (2021), UK Climate Risk Independent Assessment (CCRA3), Technical Report Chapter 4: Infrastructure
- 363 Officially known as Adaptation Reporting Power Reports
- 364 Network Rail (2023), England and Wales Strategic Business Plan Control Period 7
- 365 Network Rail (2021), Network Rail Third Adaptation Report
- 366 This would support the recommendations of the international Taskforce on Climate Related Financial Disclosures that businesses set out the impact of climate risks on their financial planning. Task Force on Climate-related Financial Disclosures (2017), Recommendations of the Task Force on Climate-related Financial Disclosures
- 367 Climate Change Committee (2022), Understanding Climate Risks to UK Infrastructure: Evaluation of the Third Round of the Adaptation Reporting Power – July 2022
- 368 Institution of Mechanical Engineers (2023), Adapting Industry to Withstand Rising Temperatures and Future Heatwaves
- 369 Energy Networks Association (2023), Standards and Guidance
- 370 Digital Twin Hub (2023), Climate Resilience Demonstrator
- 371 Gatwick Airport Ltd (2012), Third Climate Change Adaptation Progress Report
- 372 Environment Agency and Department for Environment, Food & Rural Affairs (2023), Taking an adaptive approach: Thames Estuary 2100
- 373 Climate ADAPT (2019), Flood defence framework for National Grid substations in United Kingdom
- 374 OECD (2021), Building resilience: New strategies for strengthening infrastructure resilience and maintenance
- 375 By infrastructure operators the Commission means organisations responsible for designing, building and managing infrastructure systems such as Network Rail, National Grid, water companies, and BT

- 376 Environment Agency (2023), [Flood and Coastal Erosion Risk Management Report: 1 April 2022 to 31 March 2023](#)
- 377 Thinks Insight & Strategy (2023), [Social Research for the National Infrastructure Commission to inform the second National Infrastructure Assessment: Core audience report](#)
- 378 National Infrastructure Commission (2023), [Infrastructure Progress Review 2023](#)
- 379 National Infrastructure Commission (2022), [Reducing the Risk of Surface Water Flooding](#)
- 380 National Infrastructure Commission (2022), [Reducing the Risk of Surface Water Flooding](#)
- 381 National Infrastructure Commission (2022), [Reducing the Risk of Surface Water Flooding](#)
- 382 National Infrastructure Commission (2022), [Reducing the Risk of Surface Water Flooding](#)
- 383 National Infrastructure Commission (2022), [Reducing the Risk of Surface Water Flooding](#)
- 384 National Infrastructure Commission (2022), [Reducing the Risk of Surface Water Flooding](#)
- 385 Department for Environment, Food and Rural Affairs (2021), [Flood and coastal erosion risk management. An investment plan for 2021 to 2027](#)
- 386 Environment Agency (2021), [Long-term investment scenarios \(LTIS\) 2019](#)
- 387 National Infrastructure Commission (2018), [National Infrastructure Assessment](#)
- 388 Department for Levelling Up, Housing and Communities (2022), [Flood risk and coastal change](#)
- 389 Met Office (2023), [State of the UK Climate](#)
- 390 Department for Levelling Up, Housing and Communities (2023), [Long-term Plan for Housing](#)
- 391 National Infrastructure Commission (2018), [Preparing for a Drier Future](#)
- 392 Department for Environment, Food and Rural Affairs (2022), [Water Targets: Detailed evidence report](#)
- 393 National Infrastructure Commission (2018), [Preparing for a Drier Future](#)
- 394 Environment Agency (2023), [A Review of England's Draft Regional Water Resources Management Plans](#)
- 395 Water UK (2018), [Letter to the Secretary of State](#)
- 396 National Infrastructure Commission (2023), [Infrastructure Progress Review 2023](#)
- 397 Ofwat (2022), [Leakage in the Water Industry](#)
- 398 Department for Environment, Food and Rural Affairs (2023), [Plan for Water: our integrated plan for delivering clean and plentiful water](#); Discover Water (2023), [The amount we use](#)
- 399 Department for Environment, Food and Rural Affairs (2021), [Water Stressed Areas – Final Classification 2021](#)
- 400 Frontier Economics (2021), [The Benefits of Smart Metering in the Water Sector](#)
- 401 The Commission's analysis suggested smart metering could reduce usage to 118 litres per person per day – see National Infrastructure Commission (2018), [Preparing for a Drier Future](#)
- 402 Ofwat (2022), [Creating Tomorrow, Together: Our Final Methodology for PR24](#)
- 403 Joint Nature Conservation Committee (2023), [Overview of Assessment of Change for all Indicators](#)
- 404 National Infrastructure Commission (2021), [Natural Capital and Environmental Net Gain](#)
- 405 HM Government (2018), [A Green Future: Our 25 Year Plan to Improve the Environment](#)
- 406 National Infrastructure Commission (2021), [Natural Capital and Environmental Net Gain](#)
- 407 National Infrastructure Commission (2023), [Delivering net zero, climate resilience and growth](#)
- 408 CIRIA (2019), [Biodiversity Net Gain. Good Practice Principles for Development](#)
- 409 Orsted (2020), [Response to the Secretary of State's Minded to Approve Letter. Appendix 2: Kittiwake Compensation Plan](#)
- 410 National Infrastructure Commission (2021), [Natural Capital and Environmental Net Gain](#)
- 411 Department for Environment, Food and Rural Affairs (2023), [Consultation on Biodiversity Net Gain regulations and implementation: Government response and summary of responses](#). Infrastructure projects consented under the Town and Country Planning Act will be required to achieve biodiversity net gain from November 2023. Government is also an approach to marine net gain.
- 412 Natural England (2022), [Biodiversity Net Gain: An introduction to the benefits](#)

- 413 National Infrastructure Commission (2021), [Natural Capital and Environmental Net Gain](#)
- 414 Environment Agency (2021), [Using the Power of Nature to Increase Flood Resilience](#)
- 415 Environment Agency (2023), [Reflections on Water: The good, the bad and the future](#)
- 416 Environment Agency (2023), [Water and Sewerage Companies in England: Environmental performance report 2022](#); HM Government (2021), [25 Year Environment Plan Annual Progress Report, April 2020 to March 2021](#)
- 417 Environment Agency (2023), [State of the Water Environment Indicator B3: Supporting Evidence](#)
- 418 HM Government (2021), [Storm Overflow Evidence Project](#)
- 419 Department for Environment, Food and Rural Affairs (2022), [Storm Overflows Discharge Reduction Plan](#)
- 420 Department for Environment, Food and Rural Affairs (2023), [Environmental Improvement Plan 2023](#)
- 421 Department for Environment, Food and Rural Affairs (2022), [Storm Overflows Discharge Reduction Plan](#)
- 422 For the Commission, the waste sector includes emissions from energy from waste plants which are not included under waste sector emissions in government statistics. See also Climate Change Committee (2020), [The Sixth Carbon Budget: Waste](#)
- 423 Department for Environment, Food and Rural Affairs (2023), [UK Statistics on Waste](#); Climate Change Committee (2020), [The Sixth Carbon Budget: Waste](#)
- 424 Environment Agency (2003), [Guidance on Monitoring of Landfill Leachate, Groundwater and Surface Water](#); Air Quality Consultants (2020), [Health Effects due to Emissions from Energy from Waste Plant in London](#)
- 425 Thinkinsight & Strategy (2023), [Social Research for the National Infrastructure Commission to inform the second National Infrastructure Assessment: Core audience report](#)
- 426 HM Government (2020), [The Waste \(Circular Economy\) \(Amendment\) Regulations 2020](#)
- 427 Department for Environment, Food and Rural Affairs (2023), [Environmental Improvement Plan 2023](#)
- 428 Department for Environment, Food and Rural Affairs (2022), [Environment Act Targets Impact Analysis: Waste Reduction](#)
- 429 Chartered Institute of Environmental Health (2022), [Nearly one fifth of waste cannot be recycled in England and Wales](#)
- 430 HMRC (2021), [Introduction of Plastic Packaging Tax from April 2022](#)
- 431 Department for Environment, Food and Rural Affairs (2021), [Consultations launched for major waste sector reforms](#); Department for Environment, Food and Rural Affairs (2021), [New Plans Unveiled to Boost Recycling](#)
- 432 Department for Environment, Food and Rural Affairs (2022), [Impact Assessment: Consistent Municipal Recycling Collections in England](#)
- 433 National Infrastructure Commission (2018), [National Infrastructure Assessment](#)
- 434 Department for Environment, Food and Rural Affairs (2023), [Single-use plastics ban: plates, bowls, trays, containers, cutlery and balloon sticks](#)
- 435 European Environment Agency (2020), [Early warning assessment relating to the 2025 targets for municipal waste and packaging waste: Germany](#)
- 436 National Infrastructure Commission (2018), [National Infrastructure Assessment](#)
- 437 Wales's 2022 recycling rate was 65.2 per cent for municipal waste (Welsh Government (2022) [New stats show Wales remains a high recycling nation](#)) compared to 43.6 per cent in 2010/11 (Let's Recycle (2011), [Wales Reports 43.6 per cent Recycling Rate for 2010/11](#); Department for Environment, Food and Rural Affairs (2023), [UK Statistics on Waste](#))
- 438 Department for Environment, Food and Rural Affairs (2023), [UK Statistics on Waste](#)
- 439 Ricardo (2023), [Waste Infrastructure Technology Mix report](#)
- 440 Department for Environment, Food and Rural Affairs (2023), [UK Statistics on Waste](#)
- 441 Wrap (2020), [National Municipal Commercial Waste Composition, England 2017](#)
- 442 Climate Change Committee (2020), [The Sixth Carbon Budget: Waste](#)

- 443 Commission analysis
- 444 Ricardo (2023), [Waste Infrastructure Technology Mix report](#)
- 445 Tolvik Consulting (2023), [UK Energy from Waste Statistics – 2022](#)
- 446 Commission analysis. The analysis suggests a drop off in capacity after 2050 due to assumptions about decommissioning existing capacity. This could be filled by new energy from waste capacity with carbon capture.
- 447 This assumes ETS gate fees based on government carbon credits and an emissions split of 50 per cent fossil and 50 per cent biogenic. Department for Business, Energy and Industrial Strategy (2023), [Valuation of Energy Use and Greenhouse Gas \(GHG\) Emissions](#).
- 448 Based on the Commission’s modelling of 2030 gate fees
- 449 Department for Environment, Food and Rural Affairs (2022) [Experimental Statistics on the carbon impact of waste from households managed by local authorities in England](#)
- 450 HM Treasury (2021), [Landfill Tax Call for Evidence: Ensuring the tax continues to support environmental objectives](#)
- 451 A definition of credible plans for carbon capture and storage is set out in the government’s recent decarbonisation readiness consultation. Department for Energy Security and Net Zero (2022), [Decarbonisation Readiness: Consultation on updates to the 2009 Carbon Capture Readiness requirements](#)

5. Investing for the future

- 452 ONS (2017), [A short guide to gross fixed capital formation and business investment](#) Ten per cent figure based on Commission calculations of investment in economic infrastructure, and ONS measure of chained seasonally adjusted annual gross fixed capital formation (a common whole-economy measure of investment)
- 453 Financial Times (2023), [The Nimby tax on Britain and America](#); HM Treasury (2010), [Infrastructure Cost Review](#)
- 454 Office for National Statistics (2023), [Construction output price indices](#)
- 455 Infrastructure and Projects Authority (2021), [Transforming Infrastructure Performance: Roadmap to 2030](#); HM Government (2022), [The Construction Playbook](#)
- 456 The Commission is required to demonstrate that its recommendations fall within a ‘fiscal remit’ of gross public investment in economic infrastructure of 1.1 to 1.3 per cent of Gross Domestic Product in each year between 2025 and 2055. The Commission’s remit letter can be found at: [Remit letter to the National Infrastructure Commission - GOV.UK \(www.gov.uk\)](#)
- 457 HM Treasury (2021), [Autumn Budget and Spending Review 2021](#)
- 458 Resolution Foundation (2023), [Cutting the cuts](#)
- 459 National Audit Office (2022), [Road enhancements: progress with the second road investment strategy \(2020 to 2025\)](#)
- 460 Department for Transport (2021), [Integrated Rail Plan for the North and Midlands](#)
- 461 Total public expenditure for 2022-23 is £1042.3bn. Source: HM Treasury (2023), [Public Expenditure Statistical Analyses 2023](#). House of Commons Library (2023), [Public spending: a brief introduction](#)
- 462 Nesta (2023), [The rise of indoor plumbing in the UK: lessons for the green transition](#)
- 463 European Commission (2023), [The Net-Zero Industry Act: Accelerating the transition to climate neutrality](#)
- 464 Providing zero per cent finance will come at a resource cost to government. The Commission’s analysis suggest this will range between £0.1 to £1 billion per year between 2030 and 2055. More detail is set out in Appendix A.
- 465 House of Commons Library (2023), [Fuel Poverty in the UK](#)
- 466 Aurora Energy Research (2023), [The impact of decarbonising heating in the power sector \(C\)](#)
- 467 HM Government (2021), [Transitioning to zero emission cars and vans: 2035 delivery plan](#)

- 468 See discussion in Appendix A for why the Commission has carried out distributional analysis using expenditure deciles rather than income deciles
- 469 The analysis does not account for wage growth, and so the changes in proportion of expenditure spent on infrastructure services are relative to today's levels. This is due to the difficulty of forecasting how the distribution of expenditure may change over time. Importantly, holding wage growth fixed means the Commission's distributional analysis likely overstates the proportion of household expenditure spent in infrastructure services in the future.
- 470 1974/75-1984/85 data is assumed to include gross capital expenditure on land drainage and flood protection, and is therefore consistent with the responsibilities of water companies post-privatisation. This assumption has been shown to hold for Anglian, Severn Trent and Yorkshire regional water authorities for the period 1974/75-1984/85. 2015/16-2020/21 data includes Havant Thicket Reservoir and Thames Tideway Tunnel capital investment.

6. Making good decisions, fast

- 471 The White House (2023), [Inflation Reduction Act Guidebook](#) and European Commission (2023), [The Net-Zero Industry Act: Accelerating the transition to climate neutrality](#)
- 472 Ofgem (2022), [Decision on Accelerating Onshore Electricity Transmission Investment](#), p.80
- 473 National Infrastructure Commission (2023), [Delivering net zero, climate resilience and growth](#)
- 474 National Infrastructure Commission (2023), [Delivering net zero, climate resilience and growth](#)
- 475 National Grid ESO (2022), [Modelled Constraint Costs, NOA 2021/22 Refresh](#)
- 476 National Infrastructure Commission (2023), [Delivering net zero, climate resilience and growth](#)
- 477 Department for Levelling Up, Housing & Communities (2023), [Nationally Significant Infrastructure: action plan for reforms to the planning process](#)
- 478 National Infrastructure Commission (2023), [Delivering net zero, climate resilience and growth](#)
- 479 This calculation is based on returning the system to the 2.6 year consenting times seen in 2010 and approximately three months of additional efficiencies in baseline environmental data gathering, and approximately three months of efficiencies in mitigation design.
- 480 National Infrastructure Commission (2020), [Design Principles for National Infrastructure](#)
- 481 Department for Energy Security & Net Zero (2023), [Independent report: Accelerating electricity transmission network deployment: Electricity Networks Commissioner's recommendations](#)
- 482 See for example National Grid ESO (2023), [The Pathway to 2030 Holistic Network Design](#) and Ofgem (2023), [Centralised Strategic Network Plan: Consultation on framework for identifying and assessing transmission investment options](#)
- 483 Department for Energy Security & Net Zero (2023), [Independent report: Accelerating electricity transmission network deployment: Electricity Networks Commissioner's recommendations](#)
- 484 David Parker (2009), The Official History of Privatisation
- 485 David Parker (2009), The Official History of Privatisation
- 486 Jon Stern (2014), [The British Utility Regulation Model: Its Recent History and Future Prospects](#)
- 487 National Infrastructure Commission (2019), [Strategic Investment and Public Confidence](#)
- 488 UK Regulators Network (2023), [UKRN guidance for regulators on the methodology for setting the cost of capital](#)
- 489 Ofcom (2020), [Statement: Promoting investment and competition in fibre networks – Wholesale Fixed Telecoms Market Review 2021-26](#)
- 490 Ofcom (2023), [Connected Nations: Summer update 2023](#)
- 491 National Infrastructure Commission (2019), [Strategic investment and public confidence](#)
- 492 National Infrastructure Commission (2019), [Strategic investment and public confidence](#)

493 Department for Business, Energy & Industrial Strategy and Department for Energy Security and Net Zero (2023), [Energy Security Bill Factsheet: Ofgem net zero duty](#)

494 Competition and Markets Authority (2015), [Productivity and competition: A summary of the evidence](#)

495 For example, Ofgem has decided in its new Accelerated Strategic Transmission Investment regulatory framework to exempt all transmission projects that are required to meet the government’s 2030 ambitions from onshore competition, see Ofgem (2022), [Decision on accelerating onshore electricity transmission investment](#)

496 Ofwat (2022), [Competition in strategic investment: a high-level stocktake](#)

497 National Infrastructure Commission (2018), [National Infrastructure Assessment](#)

498 National Infrastructure Commission (2018), [National Infrastructure Assessment](#)

499 UK Infrastructure Bank (2023), [Bank established as an enduring institution as key legislation receives Royal Assent](#)

500 UK Infrastructure Bank (2022), [Strategic Plan](#)

501 UK Infrastructure Bank (2022), [Strategic Plan](#)

502 UK Infrastructure Bank (2022), [Strategic Plan](#)

503 UK Infrastructure Bank (2022), [Strategic Plan](#)

504 HM Treasury (2023), [HMT’s statement of strategic priorities to the UK Infrastructure Bank](#)

505 National Infrastructure Commission (2018), [The Value of Design in Infrastructure Delivery](#)

506 National Infrastructure Commission (2018), [National Infrastructure Assessment](#)

507 National Infrastructure Commission (2020), [Design Principles for National Infrastructure](#)

508 Institution of Civil Engineers (2023), [Defining and developing the design champion role](#)

509 Institution of Civil Engineers (2023), [Defining and Developing the Design Champion Role](#)

510 Scottish Government (2021), [Local place plans: literature review and final report](#) and Planning Aid Wales (2023), [Introducing Place Plans](#)

511 Scottish Government (2021), [Local place plans: literature review and final report](#)

512 Estimates of the number of jobs required for the transition to net zero have been made, for example Green Jobs Taskforce (2021), [Report to Government, Industry and the Skills sector](#) and Future Energy Skills Programme (2023), [The Skills for a Jobs Transition](#)

513 Climate Change Committee (2023), [A Net Zero Workforce](#)

514 Institution of Civil Engineers (2018), [ICE Professional Skills](#)

515 Energy Systems Catapult (2023), [Electricity Networks Commissioner – Companion Report Findings and Recommendations](#)

516 The Resolution Foundation (2023), [Cutting the cuts: How the public sector can play its part in ending the UK’s low-investment rut](#)

517 Office for Budget Responsibility (2020), [Capital spending plans: how much will actually be spent?](#)

518 The Resolution Foundation (2023), [Cutting the cuts: How the public sector can play its part in ending the UK’s low-investment rut](#)

519 Brent Flyberg and Dan Gardner (2023), How big things get done; HM Government (2022), [The Construction Playbook](#); National Audit Office (2020), [Lessons learned from Major Programmes](#)

520 Brent Flyberg and Dan Gardner (2023), How big things get done; HM Government (2022), [The Construction Playbook](#); National Audit Office (2020), [Lessons learned from Major Programmes](#)

521 Brent Flyberg and Dan Gardner (2023), How big things get done

522 Institute for Government (2013), [Making the Games: What government can learn from London 2012](#)

523 International Monetary Fund (2022), [United Kingdom: Technical Assistance Report-Public Investment Management Assessment](#)

Appendix A: Fiscal and economic remit

- 524 See latest infrastructure progress review/baseline report
- 525 Department for Energy Security and Net Zero (2023), [Clean Heat Market Mechanism](#)
- 526 This issue is discussed further in Box 1.1 in Institute for Fiscal Studies (2013), [Household Energy Use in Britain: A distributional analysis](#)

Remit and structure of the Commission

- 527 National Infrastructure Commission (2020), [Young Professionals Panel second cohort](#)
- 528 National Infrastructure Commission (2020), [Design Group](#)

Cover shows Scout Moor Wind Farm and Naden and Greenbooth reservoirs near Rochdale, Greater Manchester (with thanks to United Utilities)

**NATIONAL
INFRASTRUCTURE
COMMISSION**

Better infrastructure for all

Windsor House
Victoria Street
London SW1H 0TL

[nic.org.uk](https://www.nic.org.uk) / [@NatInfraCom](https://twitter.com/NatInfraCom)

October 2023