



CONGESTION, CAPACITY, CARBON: PRIORITIES FOR NATIONAL INFRASTRUCTURE

Consultation on a National Infrastructure Assessment

**NATIONAL
INFRASTRUCTURE
COMMISSION**

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Foreword

Aqueducts, viaducts, roads and public buildings were the glory of Rome and have inspired every civilisation since. The Victorians are celebrated for their amazing public works: railways, bridges, parks, schools, hospitals, civic and parliamentary edifices – even London’s sewers, built by Sir Joseph Bazalgette, ending the ‘Great Stink’ and cholera and vital to London becoming the capital of the world.

The Victorian spirit is rekindling. St Pancras station is the pre-eminent symbol of the Millennium: George Gilbert Scott’s masterpiece, nearly demolished in the 1970s, reincarnated as terminus for High Speed One to the Channel Tunnel, Paris and Brussels; and for a magical month in summer 2012, gateway to the Olympic Games, the greatest festival in modern Britain since the Great Exhibition of 1851.

There is so much more to celebrate. The third Forth Bridge, opened by Her Majesty the Queen last month: a Scottish masterpiece. London’s east-west Elizabeth Line, which opens next year. The transformed centres of Birmingham, Manchester and so many other cities, led by the renaissance of Birmingham New Street and the city’s canals, Media City in Salford Quays and the Manchester Metro.

Water and electricity are cleaner and greener than ever before. Smartphones provide connectivity undreamed of by the Victorians. 2,268 miles of motorway, mostly constructed in the 1960s and ‘70s, are the backbone of the nation’s freight and passenger transport systems. Construction of HS2 begins next year: 330 miles of high-speed railway, transforming connectivity between the North, the Midlands and London. The hundred miles from Birmingham to London will be open within a decade and the HS2 Skills College opened this week in Doncaster and Birmingham.

Yet for all the achievements, investment has long been squeezed and policy has been erratic. Much of the country’s infrastructure is under strain, not keeping pace with population growth and modern requirements. The failure of our digital infrastructure to provide reliable phone and internet service is especially serious.

The delay in the planning of new national airport capacity is the most egregious failure of all. Thirteen years after a statement of state policy for the construction of a third runway at the UK’s principal hub airport, Heathrow, parliamentary consent to proceed has still not been given. All regions of the UK, which rely on Heathrow for international passenger and high value freight services, are suffering. In a Brexit Britain which will live or die by global trade, the ‘Heathrow full’ sign must be hauled down without delay.

The National Infrastructure Commission has a duty once a Parliament to assess national policy on economic infrastructure of national significance. No public

authority has previously reviewed the UK's infrastructure needs in this way, looking across sectors and taking a long-term perspective. It offers the opportunity to inject vision and purpose into how we plan, fund, deliver and operate the networks which underpin our economy and society.

This interim National Infrastructure Assessment is a milestone in that process. It identifies key priorities for consideration and consultation in preparation for the Commission's 2018 National Infrastructure Strategy, which will be published next summer and will set out its plan to equip Britain to thrive and compete globally through to 2050.

The 'three Cs' – congestion, capacity, carbon – are the key challenges highlighted in this interim assessment.

Congestion

Rising levels of congestion, driven by population growth, urbanisation and new working and living demands, are clogging the UK's cities and its transport and digital systems.

It is imperative that existing infrastructure is used more efficiently to reduce congestion. Smart systems have a key role to play, including digital technology to transform the efficiency of traffic lights, railway signalling and train operations, smart energy and water metering, and the 'internet of things' to enable remote and more efficient monitoring and operation of appliances. We need to invest more in alternatives to the private car, upgrading and expanding rail and metro systems, better facilities for cycling and walking and improved bus networks. New technology could make congestion and pollution charging for vehicles easier and cheaper to introduce in towns and cities where the impact of traffic is increasingly unbearable.

Capacity

Smart technology can reduce some infrastructure pressures significantly. For example, digital signalling and automatic train operation now enables the Victoria Line to operate 36 trains an hour. Air traffic modernisation and larger planes are allowing Heathrow to carry far more passengers, while 'smart' demand management could cut the requirement for new electricity generating capacity by up to £8 billion a year by 2030.

But new technology and congestion management are not enough: additional, modern infrastructure is also required. Heathrow is full. The UK is far behind other countries in its 4G mobile coverage, and it needs a plan to become a world leader in 5G and ultrafast broadband. Two-thirds of the UK's power stations will have closed by 2030 and new capacity is required to replace them. HS2 will treble rail capacity between the major conurbations of London, the Midlands and the North, but extra capacity is required to overcome bottlenecks on railways, motorways and inter-urban roads. Climate change is straining water storage capacity, particularly in the South East.

Housing is the greatest infrastructure capacity challenge of all, and a significant increase in the rate of homebuilding is a key imperative. An important objective of the Commission is to improve the planning of economic infrastructure – especially transport – so that it boosts housing growth in places where jobs and quality of life are best served and promoted.

Long-term plans, which Ministers and Parliament stick to, are essential to address the UK's capacity shortfalls, with sufficient investment and robust regulatory frameworks, market structures and planning frameworks to deliver them. Regulators are as important as Ministers in many of these areas: Britain's digital infrastructure is mainly the responsibility of Ofcom, the telecommunications regulator, not the Government or Parliament, with the investment required lying almost entirely with the private sector subject to licence and regulatory conditions laid down by Ofcom.

Good design must be at the heart of tomorrow's infrastructure. Good design is not just about aesthetics: it is about effective problem-solving from the outset, making infrastructure human-scale and user-friendly. And everything we do must enhance the environment: tackling air quality, protecting natural capital, reducing CO₂ emissions, improving quality of life.

Carbon

Big reductions are taking place in CO₂ emissions from electricity generation and the cost of renewable energy is falling sharply. But much more needs to be done for the UK to meet its climate change targets. Conversion to electric vehicles could further reduce CO₂ emissions – and air pollution – dramatically, but requires a substantial increase in smart charging infrastructure. The challenge of cutting, and ultimately eradicating, CO₂ emissions from domestic gas-fired heating is equally great; there is no prospect of achieving carbon reduction targets unless this is done. A balanced energy strategy, which boosts energy efficiency and takes a credible view of policy on nuclear power, carbon capture and storage, and wind, tidal and solar power, is imperative.

Infrastructure modernisation is not only the responsibility of the state and central Government. Leadership and investment must also be a top priority for regional, city and local Government across the UK.

The Governments of Scotland and Wales, and the Mayor of London have rightly put infrastructure planning at the heart of their programmes. The newly elected 'metro mayors' of the conurbations of the West Midlands, Greater Manchester, Merseyside, the West of England, the Tees Valley and Cambridge and Peterborough also have a critical role to play. They need their own infrastructure plan of priority projects, policies and delivery systems, complementing Government plans and the work of the National Infrastructure Commission. The Commission will support them in developing their infrastructure strategies.

This is why I am delighted to launch the consultation on the interim National Infrastructure Assessment in Birmingham, alongside the mayors of the West Midlands, Greater Manchester, London and other cities and regions.

I thank the Prime Minister, Ministers, the leaders of all the national political parties and of national, regional and local Governments, who have been so supportive of our work. I also thank my fellow Commissioners – Sir John Armitt, Dame Kate Barker, Professor Tim Besley, Professor David Fisk, Andy Green, Dr Demis Hassabis, Professor Sadie Morgan, Julia Prescott and Bridget Rosewell – for their magnificent contribution. Philip Graham and James Richardson, and the dedicated and highly expert staff of the Commission, have risen to this immense challenge.

The Romans are remembered not only for their infrastructure, but for what they did with it. Great infrastructure is not an end in itself; it makes everything else possible.



Andrew Adonis

Chair, National Infrastructure Commission

In brief

Britain's infrastructure must overcome major challenges if it is to meet the needs of future generations. Chief amongst these over the coming decades will be the threats posed to the country's prosperity and quality of life by congestion, lack of capacity and carbon.

None of these will be resolved by perpetuating the status quo. The need to address the UK's weaknesses in infrastructure planning is widely recognised. The establishment of the National Infrastructure Commission provides the opportunity to tackle these long-standing problems. A central responsibility of the Commission is to carry out a National Infrastructure Assessment every five years. Getting this right would give the UK in 2050 a stronger economy, increased international competitiveness, and a better quality of life.

This document marks the next phase of the UK's first National Infrastructure Assessment, setting out the Commission's vision and priorities for action, and consulting on what needs to be done to achieve them.

Victorian Britain led the world in infrastructure. The UK can lead once again if the right choices are made now. Addressing the threats of congestion, lack of capacity and carbon requires a focus on seven key priorities:

- Building a digital society: fast, reliable data services everywhere.
- Connected, liveable city-regions: linking homes and jobs.
- New homes and communities: supporting delivery of new homes.
- Low-cost, low-carbon: ending emissions from power, heat and waste.
- Revolutionising road transport: seizing the opportunities of electric and autonomous vehicles.
- Reducing the risks of extreme weather: making sure the UK can stand up to drought and flooding.
- Financing infrastructure in efficient ways: getting the right balance between public and private sectors.

Addressing these seven priorities will equip the UK with the infrastructure it most needs. The Commission's final Assessment, drawing upon responses to this consultation, will be published in 2018, setting out recommendations for how to do this.

Executive summary

Britain's infrastructure must overcome major challenges if it is to meet the needs of future generations. Chief amongst these over the coming decades will be the threats posed to the country's prosperity and quality of life by congestion, lack of capacity and carbon.

As more and more journeys are made on the UK's transport networks, traffic congestion and rail overcrowding will become increasingly common. Updated signalling on the London Underground and improved operational management of the country's busiest airports have squeezed additional capacity out of these national assets, but they are reaching their limits. New pressures placed on the nation's energy, water and digital systems, driven by population growth and social change, will similarly lead to these networks getting ever closer to overload.

It will be crucial to get more out of existing infrastructure, and technology, pricing and demand management will all have a role to play. But while these will reduce the level of investment needed in new capacity, they will not eliminate it. The high proportion of electricity generating capacity reaching the end of its life over the next fifteen years will demand an ambitious response, as will ever-rising expectations for digital connectivity. Continuing investment will be required in transport capacity, whether to alleviate bottlenecks or enhance connectivity between and within the UK's towns and cities.

The need to cut carbon emissions is no less pressing. The UK's legislated climate change targets require emissions from domestic transport, energy and waste to be close to zero by 2050. Effective policies to reduce greenhouse gas emissions from road vehicles, whilst managing demands on the electricity grid, and from domestic heating are a particular gap. Alongside this, the impacts of climate change are already being felt, through pressure on water resources and increased flood risk, and must be managed.

None of these challenges will be resolved by perpetuating the status quo, and the need to address the UK's weaknesses in infrastructure planning is widely recognised. Too often, a short-term view, often driven by political considerations, has prevailed or crucial interactions between sectors have been ignored. The persistent failure to expand airport capacity in South East England is the best known example, but far from the only one.

The establishment of the National Infrastructure Commission provides the opportunity to tackle these long-standing problems. Its members bring world-leading expertise and experience across a broad range of fields, including engineering, economics, politics, technology, finance and design. It takes a long

term perspective, looks across infrastructure sectors and makes independent recommendations, based on the best available evidence.

Throughout its work, the Commission aims to reinvent and revitalise the UK's approach to infrastructure planning and put in place robust and stable strategies which:

- Give infrastructure the right priority – choosing long-term investment over consumption
- Enable decisions to be made in good time on good projects, and not reopened
- Make full use of leading edge technology – smart infrastructure for a smart nation
- Incorporate innovation in finance and funding – managing demand and driving efficiency
- Focus on design from the beginning – good design is the starting point for delivering high quality infrastructure
- Enhance the environment and protect natural capital, including by improving air quality and driving down carbon emissions
- Involve people and businesses up and down the country – a national framework that incorporates local and regional priorities

Getting this right will give the UK a stronger economy, with digital technology supporting the UK's high tech sectors and thriving cities in every region providing jobs and housing growth. The UK will be more internationally competitive, with swift connections to the world and low cost, low carbon energy. And it will offer a better quality of life, including clean air, digital access everywhere, easy travel and security from drought and floods.

Victorian Britain led the world in infrastructure. The UK can lead once again if the right choices are made now.

The National Infrastructure Assessment

A central responsibility of the National Infrastructure Commission is to carry out an overall assessment of the UK's infrastructure requirements once every five years. The first National Infrastructure Assessment will analyse the UK's long-term infrastructure needs, outline a strategic vision to 2050 and set out recommendations to strengthen the nation's infrastructure. This draft Assessment is a major step towards fulfilling that responsibility.

The National Infrastructure Assessment covers all of the key sectors of economic infrastructure. It encompasses transport, energy, water and sewerage, flood risk, digital and waste. It is guided by the Commission's objectives to support sustainable

economic growth across all regions of the UK, improve competitiveness and improve quality of life.

To provide greater clarity around future investment in infrastructure, the Commission has been given by Government a long-term funding guideline, known as its 'fiscal remit'. This states that it should plan on the basis of annual public capital investment in infrastructure of 1.0-1.2% of GDP over the period of the Assessment – an increase over current levels. Where the Commission makes recommendations with public spending implications, these must be consistent with the fiscal remit.

Where infrastructure is funded by the private sector and the costs of any recommendations will ultimately be met by consumers, the Commission is required to provide a transparent assessment of the overall impact on bills.

Although the Commission reports to Parliament and Government, the impact of its recommendations will be felt much more widely, influencing decisions at local and regional level, and by regulators and the private sector. While some of its recommendations may relate to major new projects, in many cases the optimal course is to make better use of existing assets or managing demand, including through new technologies and smart systems.

How has the Commission got here?

- **By first agreeing the principles, scope and methodology underpinning the Assessment.** Last year, the Commission ran a consultation to explore these, publishing a **formal response** and further **Annex** late last year.
- **By running a wide call for ideas, evidence and solutions.** Following the process and methodology consultation, the Commission ran a 15-week **call for evidence** seeking a range of input from stakeholders, receiving over 260 responses.
- **By seeking diverse views across sectors and regions.** The Commission has held eight sector workshops and a series of thirteen expert roundtables probing specific infrastructure challenges. Commissioners have also met with local authorities and enterprise partnerships, businesses and infrastructure providers, holding meetings in Newcastle, Liverpool, Bristol, Birmingham, Winchester, Ipswich, Hull, Edinburgh, Wrexham, Belfast, London, Newquay and Doncaster.
- **By working closely with experts and other independent organisations.** This includes publishing a **joint paper** on strategic infrastructure planning with the OECD, and regular engagement with the Committee on Climate Change, the Natural Capital Committee, the Infrastructure and Projects Authority and the Commission's **expert advisory groups**.
- **By asking the wider public what matters to them.** The Commission worked with BritainThinks to use participatory social research to understand the public's views on infrastructure.

- **By identifying and studying four key drivers of infrastructure supply and demand.** These are technology, population and demography, economic growth and productivity, and climate change and environment. The Commission has since published papers on each.
- **And by modelling a range of scenarios across the solid waste, water, transport and energy sectors** to explore different future pressures on infrastructure. The scenarios are constructed using the four drivers and provide contrasting versions of the future. They will be used as reference points against which to sense-check infrastructure options, decisions and recommendations and provide a robust way of taking into account the substantive uncertainty when looking out to 2050. For digital infrastructure, there was a lack of suitable models available to consider long term need. For flood risk, the Commission has relied on Environment Agency modelling. More information about the Commission's modelling will be made available on the Commission's website.

Thinking long-term

By 2050, the UK's population and economy will have grown significantly. This will place substantial pressures on infrastructure. Rising demand for travel will risk creating high levels of transport congestion and delay, unless action is taken to address this. Other infrastructure sectors will also need to respond to increasing demand, whether through improving efficiency or adding capacity. The challenges facing the UK's energy sector are particularly acute, as a high proportion of capacity will be reaching the end of its working life at the same time as new demands are being placed upon it.

Meeting the challenge of climate change will require a transformation in energy generation and transport by 2050. Even so, the effects of climate change will still be felt, with higher average temperatures and an increased risk of drought and flooding. The UK's infrastructure will need to adapt to these pressures. Other major environmental challenges need to be addressed, such as air and water quality.

New and emerging technologies could have a transformational impact on business and people's lives, even if these are inherently hard to predict. Artificial intelligence, virtual reality and data analytic technologies are likely to become increasingly sophisticated and widely used, cutting costs and offering improvements in how infrastructure is operated and maintained, but placing growing demands on the UK's digital networks. Connected and autonomous vehicles will change the way people travel, but will require seamless connectivity alongside the road network. Digital resilience and security will acquire new significance.

The Commission is undertaking a study into the potential benefits of emerging technology for infrastructure productivity and efficiency. This will report by the end of 2017, informing the National Infrastructure Assessment.

Choices about how to meet the UK's infrastructure needs must also respect changing societal demands. In the current context, this includes consideration of the UK's planned exit from the European Union. Regardless of the UK's future relationship with the EU, the UK will still need clean water, efficient transport systems, strong digital connectivity and the ability to power homes and businesses. But there may still be important consequences of Brexit, for example in respect of finance and the environment.

Infrastructure has a long life. The UK relies on water systems, local roads and rail lines built in the 19th century. The National Grid was first developed in the 1920s and 30s and most of the UK's motorways were developed in the 1960s and 70s. The fibre spine laid in recent years will provide the foundations for digital networks for decades to come.

Infrastructure needs to be designed and built well. This does not mean over-specification or gold-plating. High quality infrastructure need not be lavish or cost more. But it does mean ensuring that projects are adaptable to different visions of the future, that they meet the needs of those who will use them, and that the quality of their design has been considered from the beginning. This is in part about appearance, but it is also about how infrastructure performs over the long term, what it is like to use and how it fits within its environment.

Given the central role (and poor track record) of the public sector in promoting and shaping the design of infrastructure systems and projects, others must have a voice. At times this has been done well in recent years, for example through the Commission on Architecture and the Built Environment's work (now being led by the Design Council). But there are many examples of failure too.

A national design panel for infrastructure, with a remit covering all of the main infrastructure sectors, could help ensure that any new projects improve the quality of people's lives and of the wider environment through the ingenuity, technical capability, ease of use and beauty of their design.

To improve the quality of the UK's infrastructure, it will also be important to be able to measure it. Not everything can be reduced to numbers, but the currently available metrics for infrastructure performance are often inadequate, focusing on perceptions or relative expenditure. The Commission therefore intends to develop better ways of measuring the state of the UK's infrastructure. Annex A sets out initial proposals for how these might be measured.

Better performance measures should also improve the analysis of the costs and benefits of proposed projects. Cost benefit analysis is widely used in deciding between infrastructure projects in the public sector, especially in transport. It is only ever one factor in any decision. But given the range of competing proposals for limited funds, it is inevitable that some assessment of the costs and benefits of alternatives plays a role in decision-making. The UK is generally thought to be a leader in the development of cost-benefit analysis. However, the Commission is also aware of the limitations of existing methods and intends to examine whether improvements could be made.

Infrastructure quality also depends on the availability of the right skills, the approach to construction and project management, the depth of the supply base, and the capability of Government and other infrastructure owners and operators, to act as an intelligent client. These are predominantly the responsibility of the Infrastructure and Projects Authority which advises on infrastructure delivery, but the Commission retains a keen interest and works closely with them where appropriate.

Priorities for action

The Commission has identified seven priority areas in which it believes current plans and policy frameworks fall well short of what will be required if the UK is to have the infrastructure it needs to support its long-term prosperity and quality of life:

- Building a digital society: fast, reliable data services everywhere.
- Connected, liveable city-regions: linking homes and jobs.
- New homes and communities: supporting delivery of new homes.
- Low-cost, low-carbon: ending emissions from power, heat and waste.
- Revolutionising road transport: seizing the opportunities of electric and autonomous vehicles.
- Reducing the risks of extreme weather: making sure the UK can stand up to drought and flooding.
- Financing infrastructure in efficient ways: getting the right balance between public and private sectors.

These priorities are discussed in more detail below. In the next phase of the National Infrastructure Assessment, the Commission will develop a strategy to address each of them. Responses to the analysis and emerging conclusions set out in this report will shape this.

Building a digital society

The UK needs world class digital infrastructure for its world leading digital economy. People and technology need to be able to connect with anyone or anything, anywhere at any time. This connectivity will be at the heart of a successful 21st century economy, just as electricity or railways were in earlier eras.

Over the next few years, the UK will need substantial investment in digital infrastructure. Much of this will be in the deployment of fibre optic cables, which are needed to support future requirements for both broadband and mobile networks. Fibre is the best available technology, but there are choices about how best to deploy it, because of costs and because there is a range of complementary technologies available.

Whilst the UK fares favourably on much of its superfast broadband coverage (above 30 Mbps), many areas of the country are underserved. Countries such as South Korea, Japan and Singapore have moved onto ultrafast broadband (above 300 Mbps). Whilst other countries prepare for 5G, the UK continues to lag behind in 4G availability. With Britain leaving the European Union, there is scope to reconsider the framework within which the regulator, Ofcom, is required to operate.

The UK will not be able to fully realise its digital ambitions whilst areas remain excluded. Problems are not limited to rural areas: many small and medium businesses also have their digital connectivity needs unmet. As the requirements of participating in a digital society increase, ubiquitous connectivity becomes essential. However, digital infrastructure is more costly to deploy in rural rather than urban areas. Bespoke solutions will be required.

In the next stage of the Assessment, the Commission will consider how to reduce the costs and maximise the benefits of deploying more fibre, whether the regulatory framework is sufficiently focused on investment and how to ensure rural areas do not continue to lose out in the long term.

The UK's digital infrastructure also needs to be ready to support new demands from other infrastructure sectors, as they become increasingly 'smart'. The Commission is already undertaking a dedicated study on the opportunities presented by new technology for making the UK's infrastructure more productive and will report its recommendations to Government by the end of 2017.

Smart infrastructure systems need to be resilient from the outset. The Commission will look at how to mitigate the increased potential for "system accidents" as infrastructure becomes increasingly reliant on digital technology. Wider resilience issues, including cyber security, are clearly also relevant to infrastructure, although other organisations, such as GCHQ, are leading work on these issues. After completion of the first Assessment, however, there may be a case for the Commission carrying out a more in-depth analysis of resilience, working with others, to inform a future approach ahead of its next Assessment.

Connected, liveable city-regions

Cities are the engine of the economy. The benefits of living and working in cities, along with the growing importance of the clustered, knowledge-intensive jobs located in them, have seen them recover and grow. For the UK's cities to succeed, they need effective infrastructure, including high-quality urban and intercity transport systems, integrated with wider strategies for housing and economic development.

The importance of connectivity between cities has been recognised and there is a strong pipeline of infrastructure investment to address some of the most urgent issues on the UK's strategic transport networks. After a long period of underinvestment, the Roads Investment Strategy is beginning to bring a longer-

term perspective, backed up with increases in funding and a move to longer-term funding in place of stop-start. On the railways, major projects such as HS2 and East West Rail are in development or underway.

The Commission has also previously reported on the need for action to improve intercity connectivity in the North of England, including kick-starting HS3, beginning between Manchester and Leeds, the two largest economies in the North, and an early boost in capacity on the M62. Transport for the North is leading work in this area, and is committed to delivering an integrated plan linking proposals for HS2 and HS3 by the end of 2017.

However, urban transport is too often not joined up or integrated, and most cities have lacked the funding and powers to address this. London is an exception, benefiting from strong leadership, significant funding and a clear strategy, including bold policies such as the London congestion charge.

The same is not true in most other cities. Transport investments are not always planned with housing opportunities or economic development in mind. Transport in and around cities is focused largely on personal cars. This is often inefficient and generates congestion, but city leaders have not had the powers or resources to address this.

The election of new metro mayors provides an opportunity. The UK needs successful cities in which people want to work and live in every part of the country. This will require a much greater focus on increasing the capacity of urban infrastructure, to deal with rising levels of traffic and reduce its impact on cities' economies, environment and quality of life. Congestion will never be eliminated in growing and productive cities – it is in many ways a sign of success – but effective strategies are needed to manage and reduce it, if such cities are to remain attractive places to live and work.

Technology will have an important role to play – the Commission's new technology study is looking at the potential impact of smart traffic management systems, and new ways of accessing transport, such as 'mobility as a service', will enable travellers to make better-informed choices.

But technology alone will not solve these problems. City leaders will also need to consider how to allocate road infrastructure as efficiently as possible – for example, using more road space for higher capacity modes, such as bus and, on the densest corridors, light rail, and identifying opportunities to increase cycling and walking as alternatives for shorter journeys. Congestion pricing could also provide an effective tool in managing road use, particularly at peak times, and there may be a role for Government in providing incentives for motorists to participate in such schemes and support for cities in implementing them.

It will also be crucial to consider how to ensure that city leaders have access to funding and resources to improve the operation of their infrastructure and support new capital projects. This could include prioritising funding towards city transport as

the major intercity investments currently underway are completed, and increasing locally raised revenue through capturing some of the increased land value from improved transport connections. However, the potential for land value uplift varies significantly across the country.

The Commission also wants to work directly with some individual cities to explore what strategies may be most appropriate in the context of different patterns of economic development and population and employment growth. Given the opportunities opened up by their new powers and increased autonomy, its direct engagement will focus in the first instance on supporting the recently elected metro mayors. In parallel with the Assessment the Commission will work with them on developing integrated and comprehensive infrastructure strategies. Whilst transport planning will be central to this work, the Commission will also aim to take a broader perspective, encouraging metro mayors to consider the full spectrum of potential priorities for each city-region.

Infrastructure to support housing

Housing supply has failed to keep pace with demand in the UK, especially in the highest demand areas. This has contributed to the difficulties, in particular for many young people, in finding suitable homes at an affordable cost. Infrastructure can make a contribution to accelerating house building if the right frameworks are put in place.

Housing cannot be created without the underpinning of transport and utilities, and smart, sustainable and liveable communities depend upon reliable and high-quality infrastructure. In turn, the value of new and existing infrastructure is enhanced if it enables new housing to be built, giving people greater choices of where to live and work.

The mutual benefits of infrastructure and housing have been frustrated by systemic limitations, in particular:

- Poor coordination between how new infrastructure is planned, invested in and delivered in relation to housing supply.
- A lack of responsiveness within some infrastructure frameworks to market signals, leaving infrastructure development out of kilter with local growth.

There are clear benefits to putting this right. Infrastructure and housing development should work together to help shape attractive, well-connected communities where people want to live and work.

Better coordination is needed. New technologies, such as digital mapping of existing and proposed infrastructure and developments across a broad strategic region, can be useful tools. A stronger understanding of the infrastructure landscape should enable better choices of location for new housing. Better incentives and understanding of planned development should enable infrastructure to be put in place in good time so that housing is not delayed.

Eliminating carbon emissions from energy and waste

The need to limit the potential impacts of climate change has led the UK to put in place strong long term targets for the reduction of greenhouse gas emissions. Good progress has already been made, but there is further to go. The costs of some energy supply options, in particular renewables, have decreased far more rapidly than originally predicted. New storage and demand management technologies will enable higher levels of renewable power to be used whilst retaining the flexibility to deal with peaks and troughs in demand.

This presents an opportunity to transition to a low-carbon energy system more cheaply than predicted even five years ago. But done badly, it could lead to unnecessarily high costs: low cost, low carbon is the best industrial strategy for energy.

Unfortunately, there is a gap between existing Government policies and achieving the UK's emission targets. Policies have not been implemented to enable a lowest cost transition. Despite the stability of having a long-term goal, policies have often been subject to sudden change, creating a challenging environment for private investors.

The UK needs to create efficient, low-cost infrastructure which makes the most of both emerging and existing technologies. The Commission's *Smart Power* report encouraged the removal of barriers to technologies such as storage and demand flexibility, as well as a review of the governance of electricity distribution networks. The Government and Ofgem have recently released a joint *Smart Systems and Flexibility Plan* which implements and builds on the Commission's recommendations.

Two priorities for achieving low-cost, low carbon are clear. The first is to improve energy efficiency. The UK has old and leaky buildings, which means households and firms use far more heat than should be required, pushing up consumer bills and increasing the costs of moving towards low carbon heating in the longer term. The Commission will consider how an ambitious programme of energy efficiency improvements could rectify this.

The second is maintaining a clear focus on consistently applied, well-designed competitive mechanisms, which can deliver lower cost energy than picking technologies. This does not mean that current mechanisms cannot be improved, for example by making it easier for demand management, efficiency and storage measures to compete alongside traditional generation. But it does mean providing long-term clarity to investors about the continuing use of such schemes.

However, the Commission also recognises that these approaches will not provide a complete solution in the energy sector and that for some parts of the system another approach will be needed. This leaves three big, interlocking issues on which the Commission is considering how to advise Government: on heat, nuclear and carbon capture and storage.

It will not be possible to continue to use natural gas – which is carbon-based – to heat the UK's buildings and provide hot water in the long term. There is low public

awareness of this. Options exist to change the UK's heating supply, but they are all disruptive and will all require investment. A large scale change in how the majority of buildings are heated in the UK will not happen without Government intervention. The market has failed to deliver energy efficiency improvements despite the tangible benefits they offer.

Different low carbon solutions for heat create different infrastructure needs, whether electricity or hydrogen (a carbon-free gas) is used as the primary energy source. The costs of future options are currently unclear. The Commission will be analysing this in more detail and looking at what is needed to ensure cost-effective options are available in future.

The Commission will also be looking at the potential long-term role of nuclear power and carbon capture and storage infrastructure in the energy system. These could both play a part in supporting system stability in electricity generation and providing sustainable heating, with the balance between them potentially affected by the strategic direction taken on the latter.

In the waste sector, energy from waste infrastructure has provided a more sustainable alternative to high-carbon forms of generation such as coal-fired power stations. As the carbon intensity of the energy grid falls, however, efficiency improvements will be needed to maintain this advantage. These could include siting such plants where the heat, as well as the electricity, produced could be used, or separating plastics from the waste provided to such facilities and sequestering it. Other technologies, such as anaerobic digestion, could also play a role, particularly if the biogas produced can be used as an alternative to fossil fuels for transport.

Managing demand and incentivising behaviour change are as important in reducing emissions from waste as from energy. A central element will be to ensure that the right incentives are in place for producers to reduce packaging. The 'packaging recovery note' system seeks to achieve this, but its success depends on supporting policies such as recycling targets and the landfill tax. Getting the right mix of these in place will be crucial to achieving more in this area.

A revolution in road transport

Most journeys are made by road, predominantly by car. Roads are central to freight distribution too. After 100 years of incremental change, the car is about to undergo a revolution. Connected and autonomous vehicles, even if there is still a driver at the wheel, will make road travel more comfortable and safer. Electric vehicles will change the terms of the transport debate in the UK. Removing the pollution created by road travel will radically improve air quality, as well as reducing carbon emissions.

At the same time, growing use of electric vehicles will erode and eventually all but eliminate revenues from fuel duty, the main way that driving is taxed. This will require the Government to develop a new way of ensuring road users contribute to the costs they create. Whilst new vehicles will be cleaner and safer, they will not solve the congestion problem. In fact, if driving is cheaper and more attractive, they may make it worse.

The Government needs to support electric, connected and autonomous vehicles with the right infrastructure. At present, most work on connected and autonomous vehicles is focused on changes to the car, rather than the changes to the road and how people use it. This will not enable the potential large gains to the overall system to be realised.

Society will need to make choices about what changes in road design and use are acceptable to maximise the benefits of connected and autonomous vehicles. In particular, whether motorists are willing to give up some degree of individual control to improve the overall flow of traffic. The Commission believes it is time to consider how road infrastructure and use should be replanned or redesigned to maximise the benefits of connectivity and autonomy in the long term.

The environmental impacts of road transport are severe. The Commission will also consider the best way to encourage uptake of electric vehicles to 100% of the car and van fleet by 2050, taking account of the Government's recent commitment to ban the sale of conventional petrol and diesel vehicles by 2040. Key to this will be ensuring that the charging infrastructure is in place to allow widespread uptake of electric vehicles, while managing the challenges this presents for the energy system. Smart chargers, which can adjust the rate or timing at which a vehicle is charged in the light of wider pressures on the electricity distribution network, and potentially even provide power back into the grid during periods of peak demand, could significantly reduce the cost of network upgrades. The Government needs to be planning for this now.

A new way of pricing road travel could also help tackle congestion. The Mayor of London's draft transport strategy contains suggestions for building on the London congestion charge, but elsewhere the congestion pricing debate is limited while congestion continues to increase. The ultimate goal should be to take fuller account of the costs associated with road travel, including environmental and congestion costs. This will need to be achieved incrementally, including by trialling new approaches at local and national level.

New forms of vehicle ownership and the increasing deployment and acceptance of 'black box' telematic technologies are already seeing shifts in how people think about the costs of road use, which could open up the opportunity for more transformative changes over time. If more efficient pricing systems could be introduced, many people would enjoy quicker, more reliable journeys, businesses would save costs on delays and society would benefit from fewer accidents and reduced noise. But any new system has to be accepted as fair by motorists.

Reducing the risks of drought and flooding

The UK relies on water and flood risk infrastructure that dates back in some cases more than a century. This has served it well in the past, and some significant investments and improvements, notably the Thames Tideway tunnel, are currently being made. Even so, risks are already apparent and climate change, a growing

population and higher environmental standards are increasing pressures, exacerbated by ageing infrastructure.

Low public awareness and a focus on short-term value have constrained action. About a fifth of water is wasted through leakage and there are shortcomings in asset maintenance and replacement. Attention to drought, flood and coastal risk tends to be focused in the immediate aftermath of major events, and reduce significantly thereafter.

The Commission will consider what action can be taken to improve efficiency and resilience by managing demand, reducing leakage and making water networks smarter. As in other sectors, technology will have an important role to play – water companies are beginning to deploy sensor technology to monitor flows through their networks and smart meters will also help with this, as well as encouraging consumers to reduce demand. Drones and satellite technology can assess infrastructure condition and search for potential leaks remotely. The Commission's new technology study is looking in detail at the scope to improve the management of water networks and reduce the costs of maintenance.

Even assuming ambitious deployment of new technology and increased focus on maintaining assets and reducing leaks, new capital investment in water supply infrastructure is still likely to be needed, particularly in more water constrained areas of the country such as the South East of England. The Commission will examine whether and how quickly any such supply options, including reservoirs, desalination plants or inter-regional transfers, may be needed and how best to deliver them.

Alongside this the Commission will continue to explore how Government and the water industry can take a longer-term, more joined-up perspective on flooding, drainage and sewerage to stay ahead of risks and deliver on people's expectations and ambitions.

'Green infrastructure' approaches to drainage and flood risk management, which focus on land use and river catchment management, can have wider benefits for the environment, for example supporting improved water quality and biodiversity. Changes to agricultural subsidies may provide new opportunities to support these.

But they are not necessarily effective against extreme flooding events, for which investment in more traditional defences, such as walls and barriers may still be needed. In assessing the most effective approach, however, it will important to be clear about the protection that can be delivered for different levels of funding across the range of risk management approaches.

Financing and funding infrastructure in efficient ways

The UK's infrastructure is built, owned and run by a mix of the public and private sectors. Given the constraints set out by the Government in the fiscal remit, access to private finance will continue to be key to serving the UK's infrastructure needs.

Projects can only be financed if there is a clear funding stream – a way to pay back the upfront costs. Too often, when people say a project lacks financing, it is really a symptom of the fact that there is no credible source of funding.

Finance itself is not in short supply. However, even where investors can identify the funding, Government support can improve the prospects and efficiency of financing. The private sector cannot and does not always act alone. The Government has a role to play in securing private finance: for example, mitigating the risk created by Government itself for rolling stock providers. The Government must act to maintain and strengthen the conditions for private sector investment in light of new uncertainties.

The European Investment Bank and the Green Investment Bank have played an important role in financing infrastructure by undertaking due diligence on complex and ‘first of a kind’ projects. The European Investment Bank may leave the UK market as a result of Brexit, however, and the role of the Green Investment Bank may also change after privatisation. The British pension fund market is more fragmented and at present has a lower target allocation in infrastructure assets than overseas counterparts, such as Canada. The Commission will look at the need to fill the gap and the options for doing so, including the potential for a new UK institution.

Different financing approaches and models can play a role in bringing more private finance into infrastructure, enabling projects to be built earlier or delivered better over their whole life. The UK was once a leader in public-private partnerships, but implementation has stalled. A lack of consistent evaluation of past projects makes it difficult to draw reliable conclusions on the whole life costs of comparable, publicly funded, projects using private finance compared to those wholly financed within the public sector. The Commission will consider where new procurement and financing mechanisms are best suited to help meet the UK’s infrastructure needs.

Where next?

This first Assessment cannot cover every important issue, but addressing these seven priorities will equip the UK with the infrastructure it most needs. Subsequent assessments, one every Parliament, will be able to consider wider issues and new challenges.

Any recommendations made by the Commission will focus on projects and policies of strategic national importance. Nonetheless, it will be important to understand and take account of local plans that are relevant to nationally strategic infrastructure in considering such projects, and to work with relevant local bodies in understanding the evidence base.

The Commission cannot address these challenges on its own. The Commission will continue to engage directly with stakeholders, including social research with the public, as it develops its recommendations.

Responses to this consultation should be emailed to NIAEvidence@nic.gsi.gov.uk. Please provide responses by **12 January 2018**.

Responses should be no longer than 20 sides of A4 paper. Respondents are welcome to answer all or only some of the questions set out. Respondents are not required to base their submissions around these questions but they may find them helpful in providing a focus on issues that are likely to be important in the Assessment process.

Respondents are strongly encouraged to provide details of the evidence and data which support their positions. This will enable the Commission to understand more fully the basis on which those conclusions have been reached. The Commission will work with key local and national stakeholders as part of an open and transparent process of engagement to support the consultation. In addition to its publications and the consultations that it carries out, the Commission's engagement tools include the use of expert advice and challenge, discussions with local, regional and national stakeholders, subject-focused seminars and social research.

In addition to this document, the Commission intends to publish further evidence and analysis ahead of the final National Infrastructure Assessment. This may include external analysis produced for the Commission as well as the Commission's own analysis and thinking on the issues covered by the National Infrastructure Assessment. Respondents are welcome to comment on these publications: details on how to do so will be set out alongside them.

In exceptional circumstances, the Commission will accept submissions in hard copy only. If you need to submit a hard copy, please send your response to the Commission secretariat at the address below:

National Infrastructure Assessment consultation
National Infrastructure Commission
5th Floor
11 Philpot Lane
London EC3M 8UD

The Commission may publish any submissions made. If you believe that there is a reason why your submission or any part of your submission should be considered confidential, please provide details.

The Commission is subject to legal duties which may require the release of information under the Freedom of Information Act 2000 or any other applicable legislation or codes of practice governing access to information.

Introduction

The National Infrastructure Commission

The National Infrastructure Commission was established in October 2015 to provide independent advice to Government on long-term infrastructure priorities. The members of the Commission bring expertise and experience from engineering, business, economics, politics, technology, finance and design.

As of October 2017, the Commission's members are:

- Lord Adonis (Chair): Lord Adonis was appointed as Permanent Chair of the National Infrastructure Commission on 21 April 2017 having served as Interim Chair since October 2015. He was formerly the Transport Secretary from 2009 to 2010, Minister of State for Transport from 2008 to 2009 and Minister for Schools from 2005 to 2008.
- Sir John Armit (Deputy Chair): Sir John is Chairman of the National Express Group, the City & Guilds Group, Deputy Chairman of the Berkeley Group and Deputy Chair of the National Infrastructure Commission. He was Chairman of the Olympic Delivery Authority from 2007-2014, Chairman of the Engineering and Physical Sciences Research Council from 2007-2012, a member of the Airports Commission from 2012-2015, and a member of the Board of Transport for London from 2012-2016.
- Dame Kate Barker: Dame Kate is a non-executive director of Taylor Wimpey plc and Man Group plc, and chairs the Jersey Fiscal Policy Panel. She is also chairman of trustees at the British Coal Staff Superannuation Scheme, and a pension trustee at the Yorkshire Building Society. She was a member of the Bank of England's Monetary Policy Committee from 2001 to May 2010. During this period, she led two major policy reviews for Government, on UK housing supply and on land-use planning.
- Professor Tim Besley: Professor Besley is School Professor of Economics and Political Science and W. Arthur Lewis Professor of Development Economics at the London School of Economics and Political Science. From September 2006 to August 2009, he served as an external member of the Bank of England Monetary Policy Committee.
- Professor David Fisk: Professor Fisk is Emeritus Professor of Systems Engineering Innovation at the Centre for Systems Engineering and Infrastructure at Imperial College London and a past President of the Chartered Institution of Building Services Engineers.

- **Andy Green:** Andy Green holds a number of Chairman, Non-Executive Director and advisory roles, linked by his passion for how technology transforms business and our daily lives. He chairs IG Group plc, a global leader in online trading and the Digital Catapult, an initiative to help grow the UK Digital Economy.
- **Demis Hassabis:** Dr Hassabis is the founder and CEO of DeepMind, a neuroscience-inspired AI company, bought by Google in January 2014 in their largest European acquisition to date.
- **Professor Sadie Morgan:** Professor Morgan is a founding director of leading architectural practice dRMM, alongside Alex de Rijke and Philip Marsh. The studio is renowned for creating innovative, high quality and socially useful architecture.
- **Julia Prescott:** Julia Prescott is a co-founder and Chief Strategy Officer of Meridiam and sits on the Executive Committee of Meridiam SAS. In addition, she is a non-executive director at the Emerging Africa Infrastructure Fund, Infraco Asia and Infraco Africa Investments, a non executive director of the IPFA, and a member of the Advisory Board of Glennmont Partners, a fund focussed on renewable energy.
- **Bridget Rosewell:** Bridget Rosewell is a founder and Senior Adviser of Volterra Partners, and a non-executive director of Network Rail and of Atom Bank. She was Chief Economic Adviser to the Greater London Authority from 2002 to 2012, responsible for all transport and economic impact analysis.

Lord Heseltine and Sir Paul Ruddock were also founder members of the Commission and made an immense contribution to its early work.

The Commission provides its advice in two ways. First, once every five years, the Commission is required to produce an overarching National Infrastructure Assessment. This covers all of the economic infrastructure sectors within the Commission's remit: transport, energy, water and sewerage, flood risk, digital and waste, and looks 10-30 years ahead. This document marks a key milestone in the first National Infrastructure Assessment process – setting out for consultation the Commission's analysis of the UK's long-term infrastructure needs and the priority areas for action.

Second, the Commission undertakes studies into specific infrastructure challenges. Completed studies to date have covered the long-term transport needs of London and the North of England, the options for enhancing the flexibility of the energy system, and the UK's strategy for 5G mobile communications. The Commission is currently undertaking studies into the infrastructure needs of the Cambridge-Milton Keynes-Oxford growth corridor (for which it published its interim report in November 2016) and into the potential for new technologies to improve infrastructure productivity and efficiency.

In addition, the Commission has a role in holding the Government to account for the delivery of its recommendations, where these have been accepted and incorporated in policy. This is carried out primarily through an annual monitoring report, in which the Commission will set out its assessment of the Government's progress in delivering the projects and programmes that it has recommended.

The Commission may also intervene more directly where it feels delivery is at risk. Most recently, the Commission identified twelve key infrastructure priorities on which significant progress is needed over the course of 2017.

These are:

- The Government should complete all preparatory work needed for a Parliamentary decision to be taken on a third runway for Heathrow airport, and progress other aviation policy decisions to boost air traffic capacity, particularly in the south-east of England.
- The Government should introduce the hybrid Bill for phase 2a (Birmingham to Crewe) of High Speed 2 and publish the finalised route for Phase 2b (Crewe to Manchester and Birmingham to Leeds), including connections with High Speed 3, and let the major work contracts for the project, by the end of July 2017.
- The Government should publish by the end of 2017 a single integrated plan for the first phase of High Speed 3, incorporating proposals for electrifying and upgrading the trans-Pennine (Manchester to Leeds) rail route, plans for the northern sections of HS2, and plans for the redevelopment of Manchester Piccadilly station, as set out in the Commission's High Speed North report.
- The Government should by the end of 2017 publish a plan, agreed with the Mayor of London, for the funding and phased construction of Crossrail 2, and for securing the necessary parliamentary consent, taking account of the recommendations in the Commission's Transport for a World City report.
- The Government should take a decision on planning permission for the Silvertown Tunnel by the end of October 2017. It should also announce its financing strategy for the new Lower Thames Crossing (to relieve the congested M25 Dartford Crossing), and begin the Environmental Impact Assessment process, no later than September 2017, paving the way for consultation on the detailed route in 2018 and the submission of the development consent application in 2019. And it should agree a policy with the Mayor of London for the next road crossing of the Thames in East London by the end of 2017, to enable substantial new housing development.

- The Government should publish its plan for smart energy systems, as set out in its response to the Commission's Smart Power report, including the actions it will take to enable greater deployment of electricity storage, interconnectors and demand flexibility, no later than September 2017.
- The Government should publish its firm forward plans for supporting renewable energy, at least to 2025, including the use of the remaining funds from the £730m agreed in the last Parliament, by October 2017, and specific longer-term goals in the Autumn Budget.
- The Government should publish its strategy for the decarbonisation of energy, including its emissions reduction plan, no later than October 2017, and set out its trajectory for the future level of the "carbon price floor" in the Autumn Budget.
- The Government should by the end of the year publish a strategy and timetable for replacing the services provided by the UK's membership of Euratom to support the timely delivery of the new Hinkley Point C nuclear power station and any future nuclear projects.
- The Government should, by the end of 2017, publish its final broadband Universal Service Obligation decision and set out minimum acceptable standards for mobile coverage.
- The Government and Ofcom should implement the recommendations from the Commission's Connected Future report and prepare for the widespread deployment of 5G technology from 2020.
- The Government should finalise the Strategic Policy Statement for Ofwat by the end of September 2017 and publish its review setting out proposals for the effective management of surface water flooding by the end of 2017.

The Commission's formal remit covers areas of UK Government responsibility. As summarised in the table below, in four of six sectors covered by the Commission, there is substantial devolution to the devolved Governments. Only energy and digital communications do not entail significant devolution. However, the Commission works with both the UK Government and the devolved administrations where responsibilities interact. As part of its ongoing processes of engagement the Commission has met with each of the devolved administrations, including liaising with the Welsh Government as it works to establish a National Infrastructure Commission for Wales.

Table 1: Devolved administration responsibilities, by infrastructure sector¹

Sector covered by the Commission	Devolved administration responsibility		
	Scotland	Northern Ireland	Wales
Transport	Largely devolved	Devolved responsibility	Devolved, aside from rail
Energy	Not devolved, aside from energy efficiency	Devolved, aside from nuclear	Not devolved, aside from energy efficiency
Water and sewerage	Devolved responsibility	Devolved responsibility	Devolved responsibility
Flood risk	Devolved responsibility	Devolved responsibility	Devolved responsibility
Digital	Not devolved	Not devolved	Not devolved
Waste	Devolved responsibility	Devolved responsibility	Devolved responsibility

The Commission's purpose and its principal outputs, accountabilities and duties, are set out in the *Charter for the National Infrastructure Commission*, published by the Government in October 2016. This also sets out the Government's commitment to respond to the Commission's recommendations within a specified timescale and guarantees its independence, stating that, within the remit set by Government, the Commission has '*complete discretion to determine independently its work programme, methodologies and recommendations, as well as the content of its reports and public statements.*'

The Commission focuses on infrastructure strategy. It works closely with the Infrastructure and Projects Authority which advises Government on infrastructure delivery, including project finance, supply-side capability and skills.

The National Infrastructure Assessment

Publishing a National Infrastructure Assessment once every five years is a central responsibility of the Commission. This first Assessment will analyse the UK's long-term infrastructure needs, outline a strategic vision to 2050 and set out recommendations for how these long-term needs should begin to be met. These recommendations will be made within the context of a fiscal remit set by the Government, described in more detail below.

Infrastructure strategy in the UK has in recent decades suffered from serious weaknesses. Policy uncertainty, reversals and prevarication have driven up costs and hampered delivery, with short-term political considerations often leading to decisions on controversial projects being postponed or, alternatively, taken in a rush and in the absence of objective evidence. Many projects have suffered prolonged planning delays. 'Silo thinking', with different infrastructure sectors managed by different departments, has led to decisions being taken without consideration for the effects that choices in one sector may have on another.²

The Commission's role is to enhance strategic infrastructure planning. It harnesses expertise and strategic thinking, and promotes consensus on strategic goals, working across the political spectrum and with central Government, regulators, industry, metro-mayors and local Government to develop its analysis and recommendations.

With this in mind, the following principles, on which the Commission consulted last year, have underpinned its work on the Assessment:

- **Open, transparent, engaging with a wide range of stakeholders:** The Commission has sought to capture the expertise and opinions of people from across infrastructure providers, business, central and local Government, academia, civil society and the wider public.
- **Independent, evidence-based, objective and rigorous:** The Commission has sought to form a clear, dispassionate assessment of the UK's infrastructure needs, built on extensive expertise and a robust methodology.
- **Forward looking, challenging established thinking:** Technological change is taking place rapidly, creating challenges and opportunities for the UK. The Commission has sought to assess the impact of technology on the supply of and demand for infrastructure services and look to make recommendations which are affordable in and robust to multiple future scenarios.
- **Comprehensive, taking a whole system approach, understanding and studying interdependencies and feedbacks:** The Commission has sought to assess the UK's infrastructure system as a whole, looking across sectors, and identifying and exploring the most important interdependencies and resilience implications.

The Assessment provides an important opportunity to strengthen the UK's approach to infrastructure planning. It builds on earlier work undertaken by the Institution of Civil Engineers in their National Needs Assessment.³ Its long-term perspective and coverage of the full range of economic infrastructure sectors mark a crucial shift from the siloed decision-making of the past, allowing the key cross-cutting themes and issues to be identified and reviewed. The independence of the Commission from both Government and industry will enable it to develop a strategy that is in the long term interests of the UK's present and future population. The wide-ranging engagement and consultation processes that underpin the Assessment aim to increase transparency and secure a broad consensus around its recommendations, including from all sides of the political divide.

Figure 1: The case for an independent National Infrastructure Assessment

Problems	Solutions
Lack of long-term strategy leading to a piecemeal approach	A clear strategic vision, encompassing all infrastructure sectors
Siloed decision-making with no common approach between sectors	A structured methodology to consider interdependencies and priorities across sectors
Fragile political consensus and short-term considerations cause uncertainty for investors	Propose recommendations consistent with a long-term objective
Lack of transparency, inadequate consultation and engagement which hinder consensus	Wide engagement and consultation
Innovative solutions and risky ideas are politically difficult decisions to take	Consider all potential solutions, including challenging ones
There needs to be better consideration across sectors of the UK's carbon targets	Assessment will be compatible with all legally binding and long-term obligations including carbon targets
Government not held to account for delivering infrastructure	Objectively scrutinise Government action

In line with all of the Commission's work, the Assessment is guided by the Commission's three overarching objectives:

- supporting sustainable economic growth across all regions of the UK;
- improving competitiveness;
- improving quality of life.

As set out in the response to the consultation on process and methodology for the Assessment, the Commission intends to interpret the term 'sustainable' in its objectives as meaning environmentally, economically and fiscally sustainable.⁴

The Commission's role is not only to assess the case for major capital investments, such as new power stations or rail links. Making better use of existing assets or managing demand for infrastructure may offer a more cost effective or sustainable solution in many cases.

Throughout its work on the Assessment, the Commission has therefore looked at both the demand for and supply of infrastructure services, such as power, water, travel or communication, as well as assessing the UK's infrastructure assets, such as roads or fibre optic cables. This has ensured that as well as considering the case for new capital investments, such as new roads or power stations, the Commission has also considered approaches, for example smart metering or peak time charging, that enable better use to be made of existing assets.

The process which the Commission has followed in undertaking this first phase of the Assessment is summarised in the box below.

How has the Commission got here?

- **By first agreeing the principles, scope and methodology underpinning the Assessment.** Last year, the Commission ran a consultation to explore these, publishing a **formal response** and further **Annex** late last year.
- **By running a wide call for ideas, evidence and solutions.** Following the process and methodology consultation, the Commission ran a 15-week **call for evidence** seeking a range of input from stakeholders, receiving over 260 responses.
- **By seeking diverse views across sectors and regions.** The Commission has held eight sector workshops and a series of thirteen expert roundtables probing specific infrastructure challenges. Commissioners have also met with the devolved administrations, local authorities and enterprise partnerships, businesses and infrastructure providers, holding meetings in Newcastle, Liverpool, Bristol, Birmingham, Winchester, Ipswich, Hull, Edinburgh, Wrexham, Belfast, London, Newquay and Doncaster.
- **By working closely with experts and other independent and advisory organisations.** This includes publishing a **joint paper** on strategic infrastructure planning with the OECD, and regular engagement with the Committee on Climate Change, the Natural Capital Committee, the Infrastructure and Projects Authority and the Commission's **expert advisory groups**.
- **By asking the wider public what matters to them.** The Commission worked with BritainThinks to use participatory social research to understand the public's views on infrastructure, and ran a workshop with Sustainability First, bringing together individuals from a range of age groups and backgrounds to examine how consumer expectations and preferences may develop over the coming decades.
- **By identifying and studying the key drivers of infrastructure supply and demand.** These are technology, population and demography, economic growth and productivity, and climate change and environment. The Commission has published discussion papers on each and sought views on the analysis presented.
- **By modelling a range of scenarios across the solid waste, water, transport and energy sectors to explore different future pressures on infrastructure.** The scenarios are constructed using the four drivers and provide contrasting versions of the future. They will be used as reference points against which to sense-check infrastructure options, decisions and recommendations and provide a robust way of taking into account the substantive uncertainty when looking out to 2050. For digital infrastructure, there was a lack of suitable models available to consider long term need. For flood risk, the Commission has relied on Environment Agency modelling. More information about the Commission's modelling will be made available on the Commission's website.

Undertaking a National Infrastructure Assessment for the first time is a significant challenge. The UK has not previously considered its long-term infrastructure needs in this way and few, if any, countries have attempted a comprehensive infrastructure planning process of this kind.

Crucial to the Commission's ability to rise to this challenge, therefore, will be the quality and breadth of its engagement with stakeholders and experts, and the strength of the evidence base and analysis that it is able to develop as a result. The responses to this consultation will be a central part of that process. Chapter 8 explains how to respond to the consultation.

The fiscal remit

The Commission's 'fiscal remit' was set out in a letter from the Chancellor of the Exchequer to the Chair of the Commission on 23 November 2016.⁵ This stated that:

"The [Commission] 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 1.0% and 1.2% of GDP in each year between 2020 and 2050."

The fiscal remit is therefore a spending envelope for capital expenditure in economic infrastructure. It does not include day-to-day ("resource") costs nor spending by devolved administrations. It is important to note, however, that it does not distinguish between local and national investment, so even where projects are funded in part or in whole from local sources (as is the case for Crossrail) the total cost still needs to be accommodated within the remit. Direct private sector contributions would not be counted, but capital spending funded by additional local taxes such as Supplementary Business Rates would.

Public expenditure on infrastructure within the Commission's remit is mainly focused on transport, waste and flood defences, plus some targeted support for digital communications, with the other infrastructure sectors being owned and operated by the private sector. In those sectors which are predominantly publicly funded, the fiscal remit does not only cover new infrastructure investment but also those projects to which the Government is already committed, such as HS2, as well as ongoing capital expenditure on renewing and enhancing relevant networks (such as funding for the Highways England Roads Investment Strategy and for Network Rail Control Periods).

In other sectors, such as energy and water, the fiscal remit does not cover financial measures such as guarantees or contracts for difference used to promote the Government's policy objectives in these sectors. Nonetheless, if the Commission were to recommend direct public funding of capital projects or programmes, this would fall within the remit.

As set out in Chapter 7, the remit represents an increase on current levels of public investment in infrastructure, which totalled roughly one per cent of GDP in 2016-17, although prioritisation will still be needed given the scale of the investment being contemplated over the coming decades, and particularly in the 2020s.

Where infrastructure is privately funded – for example, most of the digital, energy and water sectors – the Commission’s recommendations are likely to impact on business and consumer bills rather than public expenditure. In these cases, the Charter and the remit require that the Commission provides “*a transparent assessment of the impact on costs to businesses, consumers, public bodies and other end users of infrastructure that would arise from implementing a proposal*”.

Prioritisation decisions will ultimately reflect the judgement of the Commissioners. As set out in the response to its consultation on the process and methodology for the Assessment, the Commission will draw upon the broadest range of evidence to inform these judgements, including:

- Scenario-based modelling and forecasting to understand how the UK’s infrastructure requirements could change in response to different assumptions about the future.
- Quantitative modelling of ‘baseline’ outcomes in these scenarios, and of packages of policy proposals in the most relevant scenarios, to allow an assessment of the robustness of policy options to future uncertainty.
- Stakeholder expertise and opinions, captured both through formal calls for evidence and consultation and through face-to-face engagement events.
- Social research to understand the views of the general public, using a mix of deliberative techniques and survey data.
- Analysis of local infrastructure plans and strategies from relevant local and combined authorities and Local Enterprise Partnerships, and national infrastructure plans and strategies from relevant Government departments and economic regulators, as well as direct engagement with local and national partners on infrastructure planning issues.
- Roundtables and other engagement with experts relevant to a sector or issue on which focused input is required, including through the Commission’s expert advisory panels.
- Commissioning new analysis or literature reviews on key topics.
- Cost-benefit analysis of individual projects and proposals (although the Commission recognises the limits of standard cost-benefit analysis approaches, and is exploring improvements that can be made to current methodologies).
- Identifying and learning from international best practice.

Considering the demand for infrastructure over thirty years

A key element of the development of the Commission's vision and priorities has been to assess how demand for infrastructure may evolve over the coming decades.

Looking at demand over a period of thirty years or more is a difficult task. To explore it, the Commission reviewed four drivers of infrastructure demand and, in some cases, supply: population change and demography, technological change, economic growth and environment and climate change. Over the last year, it has published discussion papers on each of these, which have been used to inform the creation of a set of scenarios for the UK in 2050.⁶

Population change and demography

The size of the population, its composition and its geographical distribution have a direct impact on the demand for infrastructure services. The UK population was estimated at 65.1 million people in 2015 and is projected to increase between now and 2050. The uncertainty is large, so the Commission has decided to use a range based on projections by the Office for National Statistics, which shows a UK population of between 73.7 million and 80.1 million people in 2050.

Infrastructure is inherently spatial. Infrastructure service demand will therefore vary across the country depending on where people choose to live and where businesses locate. Recent trends would imply a continued urban revival. London's population is projected to rise particularly strongly. But longer historical trends and constraints on housing supply imply this is uncertain. For this reason, the Commission is also considering a scenario where population growth is distributed more equally around the country over the coming decades.

Technological change

Technological changes, if exploited effectively, could have a transformational impact on infrastructure and people's relationship with it over the next thirty years. Innovations such as smart motorways can enable an increase in the effective capacity of existing infrastructure. Some technologies, such as mobile phones, can create demand for more infrastructure and others may even lead to a decline in the usage of an existing infrastructure system.

Infrastructure assets tend to be built to last several decades, meaning much of the impact of technology will be realised through its application to existing infrastructure. As well as increasing capacity, there is the potential to lower operating costs through use of technologies such as sensors and drones. Technology also has the potential to lower the cost of constructing new infrastructure.

Despite the challenges associated with forecasting technological change, the Commission is explicitly considering technological change as an input into its scenarios. The rationale for this is that although policy can act as an incentive to the dissemination of technology, certain technologies will diffuse in any case and could significantly impact infrastructure needs, e.g. electric vehicles.⁷

The Commission is also currently undertaking a **study** looking at how new technology can improve infrastructure productivity, which will report by the end of 2017.

Economic growth

As people get richer they tend to use more infrastructure services. Therefore, as incomes grow so will the demand for infrastructure. The Commission has chosen to explore three variants of long-term growth and productivity, which aim to reflect the significant uncertainty around future GDP per capita. These range between growth in GDP per capita of 0.7% and 1.9% per year.⁸

Infrastructure investment itself can affect economic growth in several ways. Improving the quantity and quality of infrastructure services can lower costs for businesses. For example, a more efficient transport network will reduce the cost of distribution.

Infrastructure can directly enable changes which increase productivity. For example, broadband enables customers and suppliers to find one another and interact at very low cost, improving the efficiency of a wide range of services, such as travel agencies, retail and banking.

Infrastructure is essential to the efficient working of the housing and labour markets. Without infrastructure, housing cannot be built where people want to live, and people cannot travel between where they want to live and where jobs are located. Firms and workers are more productive when they cluster together and can benefit from learning, knowledge sharing, specialisation and access to deeper labour markets.

Environment and climate change

The biggest impact of infrastructure on the global environment is via the emissions of the greenhouse gases that drive climate change. This is particularly significant in the energy and transport sectors. Pollution from infrastructure also impacts local air and water quality. Infrastructure is recognised as one of the key pressures which prevents bodies of water achieving 'good' ecological status. Pollution from diesel vehicles is now the most significant air quality threat to human health in the UK.⁹

Climate change will have major impacts on infrastructure service provision both through the need to reduce emissions and to adapt to the effects that are already inevitable. These include the increased likelihood of both droughts and floods, which will have a direct impact on infrastructure demand, as well as increasing the

level of risk for other infrastructure systems. The National Infrastructure Assessment will take account of the legal commitment to cut greenhouse gas emissions by at least 80% from 1990 to 2050.

The environment, as well as people, can benefit from the provision of green infrastructure, such as wetlands that mitigate flooding, clean polluted water and are an enjoyable place to visit. This is the case where the design of infrastructure works in concert with environmental processes.

Scenario analysis

No forecast of the future will be right. The Commission recognises the high levels of uncertainty which surround the decisions that need to be taken over the next thirty years. This is a key reason for using different scenarios of the future to inform the National Infrastructure Assessment and its recommendations. For this interim document, baseline scenarios have been modelled across the energy, transport, waste and water sectors, using both Government and academic models.

The Commission is grateful for the support it has received from the Infrastructure Transitions Research Consortium and from Government analysts in supporting this modelling. The Commission has made use of these existing models, rather than attempt to build its own models. However, the inputs into the models reflect the Commission's scenarios and judgements, not those of the model owners, and responsibility for the conclusions therefore lies with the Commission. More discussion of the results is available on the Commission's website.

In the face of significant uncertainty, this will allow the Commission to consider which interventions are a good idea in all probable worlds and which, despite a cost attached to them, are worth investing in as they enable alternative pathways to remain possible. This may include behavioural and regulatory solutions, on both the demand and supply sides, as well as new capital investments.

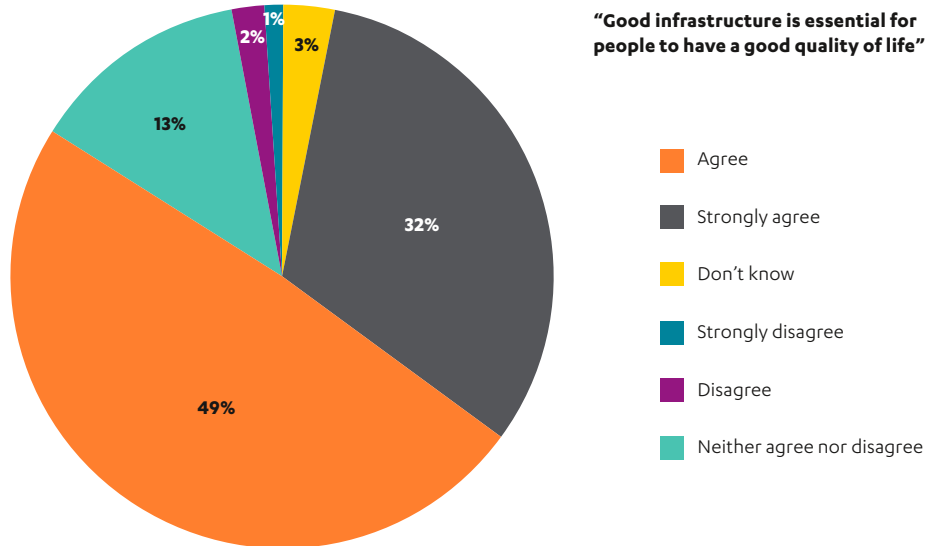
Choices about how to meet the UK's infrastructure needs must also respect the changing demands of politics and society. In the current context, this includes consideration of the UK's planned exit from the European Union. Regardless of the UK's future relationship with the EU, the UK will still need clean water, efficient transport systems, strong digital connectivity and the ability to power homes and businesses. But there may still be important consequences, for example in respect of finance and the environment.

What do users of infrastructure care about?

To inform its vision and priorities, the Commission undertook nationally representative polling combined with three workshops held in London, Nottingham and Colne in Lancashire.

The following key findings emerged:

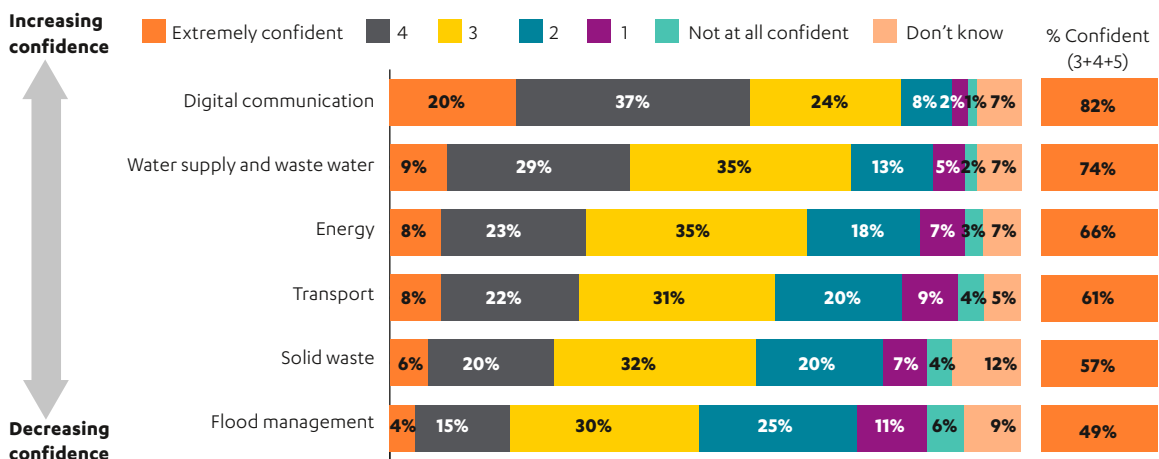
Figure 2: Infrastructure and quality of life



- Infrastructure, particularly transport and increasingly digital technology, is considered critical to supporting a good quality of life.
- People are concerned about many aspects of infrastructure, including transport and flood management. However, whilst there is support for spending on increased resilience against flooding, views on increased Government transport spending are more mixed.
- There is concern about levels of waste and support for action to combat excess packaging.
- There is significant optimism about the digital communications sector.
- There is low awareness of challenges facing the water sector.
- Cost is a primary concern in energy, though environmental impact is also considered important.

- There is a desire for a resilient infrastructure system in the future, even if this means investing now and putting up with disruption. But people want to see tangible benefits.

Figure 3: Public confidence in infrastructure systems



Promoting better design

Over centuries, well-designed infrastructure projects – many controversial in their day – have added to the quality of the surrounding environment. This did not happen by chance, but by building in good design from the start. Similarly, towns and cities are more likely to be attractive places to live and work when infrastructure and the built environment are considered in parallel, not as isolated projects. New technologies have the greatest impact when they are well-designed and simple to operate.

Good design is essential to achieve value over the long term. Well-designed infrastructure can measurably add to its surrounding environment, without necessarily having to cost more. Elaboration, cost and grandeur are often the enemies of excellence in design. This is not merely a question of what infrastructure looks like, it is also about how it performs, and does so over the long term, and what it is like to use.

Given the central role, but often poor track record, of the public sector in promoting and shaping the design of infrastructure systems and projects, it is important to ensure that there are opportunities to bring a wider range of voices to bear, especially those with expertise and knowledge of design and related fields. The Commission on Architecture and the Built Environment provides a good example of how this can be achieved, and drove many improvements in the design of public sector building projects. Although it has been disbanded, its functions are being taken forward by the Design Council.

The importance of design quality in infrastructure is increasingly recognised. The HS2 Design Panel has made a significant difference in raising the level of ambition for design in the UK's largest single infrastructure project, and a similar panel has been established by Highways England to champion excellence in road design. The Mayor of London has also appointed 50 Design Advocates, whose role is to set and apply ambitious design standards for the capital, leading by example and advocating best

practice. In each case, these groups bring together leading professionals from a range of backgrounds, including architecture, sustainable development, product and brand design, heritage, procurement and engineering.

Building on these examples, a national design panel for infrastructure, with a remit covering all of the main infrastructure sectors, could help ensure that any new projects improve the quality of people's lives through the ingenuity, technical capability, ease of use and beauty of their design.

Key aims of any such panel would be to advise on strategic design issues, help solve complex problems, anticipate future needs, share lessons learned, spot opportunities and highlight potential synergies between infrastructure investments in different sectors. Infrastructure can have significant social and environmental impacts, and a design panel would ensure that sensitivity to local communities, as well as to natural and urban landscapes, are at the heart of its design.

As a first step, an overarching design vision could be developed through a collaborative process involving leading design professionals and representatives of infrastructure delivery organisations. This would set out the core design principles that the design panel would uphold, as a critical friend to those responsible for infrastructure projects.

Measuring the performance of infrastructure

Any assessment of the UK's infrastructure needs reliable measures of existing performance. Too many current assessments of infrastructure quality, such as the league tables prepared by the World Economic Forum, are inadequate, being based either on perceptions or levels of expenditure.¹⁰

A key long-term objective for the Commission is to develop a clear set of metrics to allow it to assess and track the performance of the UK's infrastructure over time. With such a framework in place, it will be possible to make more robust and sophisticated comparisons of infrastructure quality between different areas of the UK, and potentially between the UK and other countries, than is currently feasible.

These metrics will be guided by the Commission's three overarching objectives: supporting sustainable economic growth across the regions of the UK; improving competitiveness; and improving quality of life. Given the complex and multi-faceted nature of these objectives, it will be extremely difficult to measure directly how far they are being achieved over time. However, it is clear that infrastructure supports the Commission's objectives in a number of different ways:

- **supporting sustainable economic growth across all regions of the UK:** high-quality transport and digital infrastructure and low costs of infrastructure services used by firms support productivity and economic growth; while environmental action on climate change is essential to maintaining long-term global prosperity.

- **improving competitiveness:** low cost infrastructure services – which are inputs into all other production – support competitiveness, and high quality international connectivity is essential for exports of British goods and services.
- **improving quality of life:** high quality connectivity to friends and family supports quality of life, as do environmental factors such as clean air and water and the quality of the urban realm. The cost of infrastructure affects people’s standard of living; while resilience against shocks such as drought and flooding are essential to quality of life.

The Commission has therefore identified service quality, cost, resilience, and environmental sustainability as the four ‘dimensions’ of infrastructure performance for which it is seeking to identify suitable metrics. Annex A sets out initial proposals for how these might be measured.

Cost-benefit analysis

Better performance measures should also improve the analysis of the costs and benefits of proposed projects. Cost-benefit analysis (also known as economic appraisal) is widely used in deciding between infrastructure projects in the public sector, especially in transport. It is only ever one factor in any decision. But given the range of competing proposals for limited funds, it is inevitable that some assessment of the costs and benefits of alternatives plays a role in decision-making.

The UK is generally thought to be a leader in the development of cost-benefit analysis. Official guidance is periodically updated and has attempted to address some of the issues raised.¹¹ However, the Commission is also aware of the limitations of existing methods. The Commission has engaged with a range of experts and interested stakeholders to better understand these limitations (see box) and intends to follow this up to consider whether improvements could be made.

Some issues with cost-benefit analysis

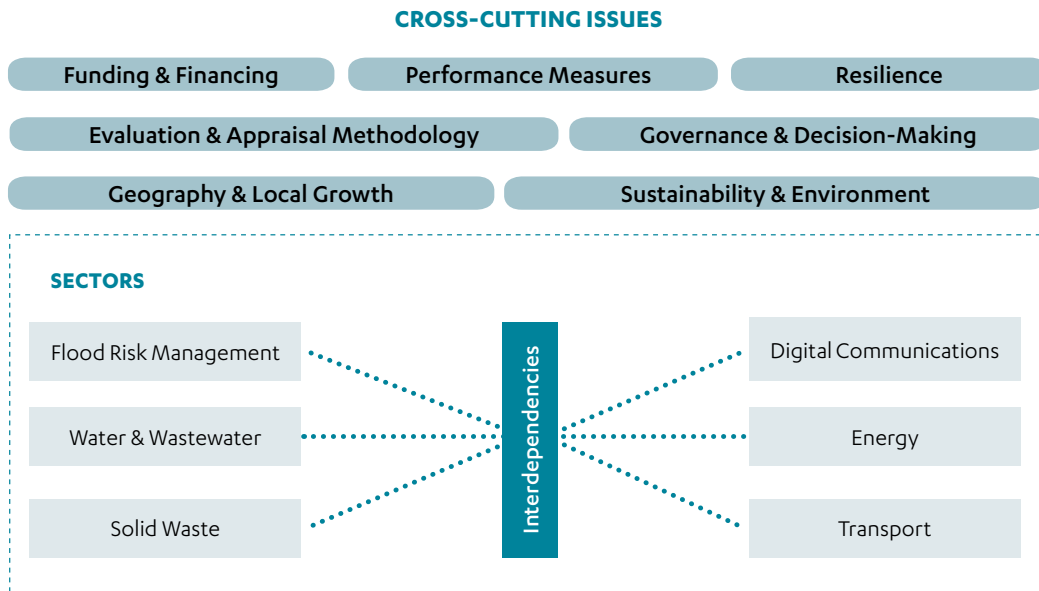
The Commission has engaged with a range of stakeholders and experts on cost-benefit analysis. A number of issues were raised, including that:

- The methods used to inform transport investment decisions do not currently support integrated transport and housing planning. Standard economic appraisal methods for transport are good at assessing benefits, such as quicker or safer journeys, but it is harder to capture the benefits from new housing or commercial developments enabled by transport projects. This may reduce the incentive to integrate transport and housing decisions. Some stakeholders argue that it creates a bias towards investment in links between cities rather than urban transport projects. However, the Commission also heard that existing alternative methods, such as ‘land use transport interaction models’ can be hard to interpret, rely on opaque or proprietary methods, and often produce estimates which are hard to reconcile with the results of robust studies of previous, similar projects. The Commission will explore whether robust alternative approaches can be developed.
- Cost-benefit analysis has an important role to play in ensuring robust decisions are made, but too often the process starts with an overly complex analysis of an overly narrow list of options. The Commission is interested in how a wider range of options could be considered in the early stages of decision-making, using simpler appraisal to identify better initial options. More complex analysis could then be applied later in the process, where it is likely to be more useful.
- Cost-benefit analysis can allow consideration of a wide range of factors, such as environmental impacts, impacts on human health or quality of life factors, such as the quality of good architecture. However, concerns were raised that some valuations are poorly understood or measured; values are not always used even when available; and some important issues may not be capable of being valued at all with current techniques. The Commission will be guided in making its recommendations by the impact on the Commission’s objectives to: support sustainable economic growth across all regions of the UK; improve competitiveness; and improve quality of life.
- Standard cost-benefit analysis methods are intended to capture relatively small effects to overall systems (‘marginal impacts’). Many projects are of this nature: the UK has a substantial existing stock of infrastructure, so enhancements are often small by comparison. But some changes need to be assessed at system level: for example, new digital infrastructure may not simply provide a small addition to existing capabilities. The Commission will explicitly recognise this limit of standard cost-benefit analysis when considering system-wide changes.

The Commission's Priorities

The Commission has reviewed the six sectors in its remit and the interdependencies between them, alongside a range of cross-cutting issues, to determine the key areas of focus for the first Assessment, as summarised in Figure 4.

Figure 4: Sectors and cross-cutting issues



On the basis of this analysis, it has identified seven priorities where current policies and programmes appear inadequate to meet the challenges of the future. These are:

- Building a digital society: fast, reliable data services everywhere.
- Connected, liveable city-regions: linking homes and jobs.
- New homes and communities: supporting delivery of new homes.
- Low-cost, low-carbon: ending emissions from power, heat and waste.
- Revolutionising road transport: seizing the opportunities of electric and autonomous vehicles.
- Reducing the risks of extreme weather: making sure the UK can stand up to drought and flooding.
- Financing infrastructure in efficient ways: getting the right balance between public and private sectors.

The following chapters consider each of these priorities in turn. In each case, the Commission sets out:

- (a) why action is needed;
- (b) the weaknesses of the current position;

- (c) the key areas for action and the major options that have been identified so far, focusing in particular on the role of new technology, the funding implications of any new policies or investments, and the options for making sure that change happens;
- (d) what the UK would look like in 2050 if the Commission's vision were met;
- (e) the specific questions on which the Commission is seeking responses through its consultation on this document.

Addressing these priorities will be central to providing the UK with the infrastructure it needs over the next 30 years. At the heart of this will be ensuring that the UK has a world-leading digital infrastructure, as this is not only increasingly central to daily life but also of rapidly growing importance to the efficient management, operation and maintenance of every other infrastructure sector. It is with this issue, therefore, that the Commission's Assessment begins.

Consultation Questions

The UK is preparing to leave the European Union. While the terms of exit are currently uncertain, this raises a wide range of issues. The Commission is focused on strategic issues (eg the implications for environmental policies, such as the Habitats Directive) rather than delivery issues, which are the responsibility of the Infrastructure and Projects Authority (eg the future supply of skilled labour).

- 1) **How does the UK maximise the opportunities for its infrastructure, and mitigate the risks, from Brexit?**

Good design is essential to ensuring infrastructure that lasts, is useful and enhances both its environment and the quality of life of citizens.

- 2) **How might an expert national infrastructure design panel best add value and support good design in UK infrastructure? What other measures could support these aims?**

The Commission proposes to identify a small set of high-level metrics to assess the UK's progress in achieving high quality, resilient, affordable and sustainable infrastructure. The Commission's initial proposals are set out in Annex A.

- 3) **How can the set of proposed metrics for infrastructure performance (set out in Annex A) be improved?**

Cost-benefit analysis is a key source of evidence used to inform decisions on infrastructure investments. However, too often it narrows down to a preferred option without giving sufficient consideration to alternatives.

- 4) **Cost-benefit analysis too often focuses on producing too much detail about too few alternatives. What sort of tools would best ensure the full range of options are identified to inform the selection of future projects?**

References

- ¹ Based on discussions with officials in the UK Government
- ² See for example: The Labour Party (2013) The Armitage Review; LSE Growth Commission (2013) Investing for Prosperity: Skills, Infrastructure and Innovation
- ³ Institution of Civil Engineers (2016) National needs assessment, a vision for UK infrastructure
- ⁴ National Infrastructure Commission (2016) The National Infrastructure Assessment process and methodology consultation response
- ⁵ HM Treasury (2016) Remit letter for National Infrastructure Commission
- ⁶ National Infrastructure Commission (2016) The impact of population change and demography on future infrastructure demand
- ⁷ National Infrastructure Commission (2016) The impact of technological change on future infrastructure supply and demand
- ⁸ National Infrastructure Commission (2017) Economic growth and demand for infrastructure services
- ⁹ National Infrastructure Commission (2017) The impact of the environment and climate change on future infrastructure supply and demand
- ¹⁰ World Economic Forum (2016) The global competitiveness report 2016-2017
- ¹¹ See for example: Department for Transport (2016) Understanding and valuing impacts of transport investment, updating wider economic impacts guidance.

1. BUILDING A DIGITAL SOCIETY

DIGITAL CONNECTIVITY WILL BE AT THE HEART OF A SUCCESSFUL 21ST CENTURY ECONOMY:

Forecasts suggest there will be

156million

'Internet of Things' connections in 2024 – up from 13.3million today



The UK's digital economy represents

12.4%

of GDP – the largest in any G20 nation

Increased broadband speeds could add

£17billion

to UK output by 2024



BUT – WITHOUT FURTHER INVESTMENT, THE UK RISKS FALLING BEHIND.

IN 2015, THE UK RANKED:



9th

out of 18 countries for 4G outdoor population coverage by at least one mobile operator



Nearly

25%

of premises in rural areas do not receive a decent broadband service



17th

out of 19 countries for access to full fibre connection



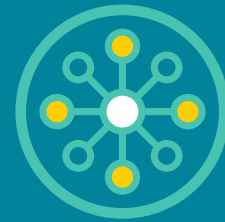
DIGITAL AT THE HEART OF EVERYTHING

A Better Future



World-class digital connectivity

– seamless, universal, without constraint



An integrated strategy for fixed and mobile networks

to capture all benefits from digital infrastructure investment



A supportive environment to deploy fibre technology

and thousands of new small cells for 5G



A digital champion

to ensure digital is at the heart of everything



Smart infrastructure nationwide

improving ease of use, lowering costs and increasing efficiency



Resilient digital and smart infrastructure

designed to mitigate malicious acts and system failures from the start

Sources: Ofcom, DCMS, BCG

The need for action

Connect with anyone or anything, anywhere at any time

The UK has a strong digital economy. It is at the cutting edge of digital innovation, research and technology. The UK's digital economy is the largest in any G20 nation as a percentage of GDP.¹ This advantage is creating new jobs, start-ups and possibilities.

Digital connectivity will be at the heart of a successful 21st century economy, just like electricity or railways in earlier eras. The UK's digital infrastructure needs to be world class, to avoid limiting the UK's digital ambitions. These ambitions contribute directly to the UK's economic growth, its international competitiveness and its citizens' quality of life.

Future expectations for digital communications are high. Consumers expect the UK's digital infrastructure to improve over the next 30 years. Many want to see the UK being a global leader.² The UK will need world-leading, high-quality connections through 5G mobile and ultrafast broadband.

Communications networks drive economic growth and foster social inclusion.³ As with other kinds of infrastructure, they provide greater benefits to everyone when they have more users – known as the 'network effect'.⁴ Past generations of communications technology, such as the postal service and telephone network in the 19th and 20th centuries, generated their highest economic benefits when coverage became near-universal.⁵

Poor digital connectivity is no longer acceptable. In the past, the UK had the foresight and ambition to connect everyone to electricity, water and transport networks. The benefits today are obvious. The same ambition is needed now for digital infrastructure.

Fixed and wireless can no longer be considered in isolation

Fixed and mobile networks have developed separately but are becoming increasingly similar (see Figure 1.1). Some devices – especially smartphones – integrate both, switching seamlessly between Wi-Fi and mobile. Devices are becoming less likely to be connected directly by wires to fixed networks. Instead, they are increasingly likely to connect via Wi-Fi or Bluetooth, which in turn is connected to the fixed network (eg via a Wi-Fi router). Although they work in different ways, both mobile and Wi-Fi use the electromagnetic spectrum to transmit and receive data, in the same way as radio or broadcast television.

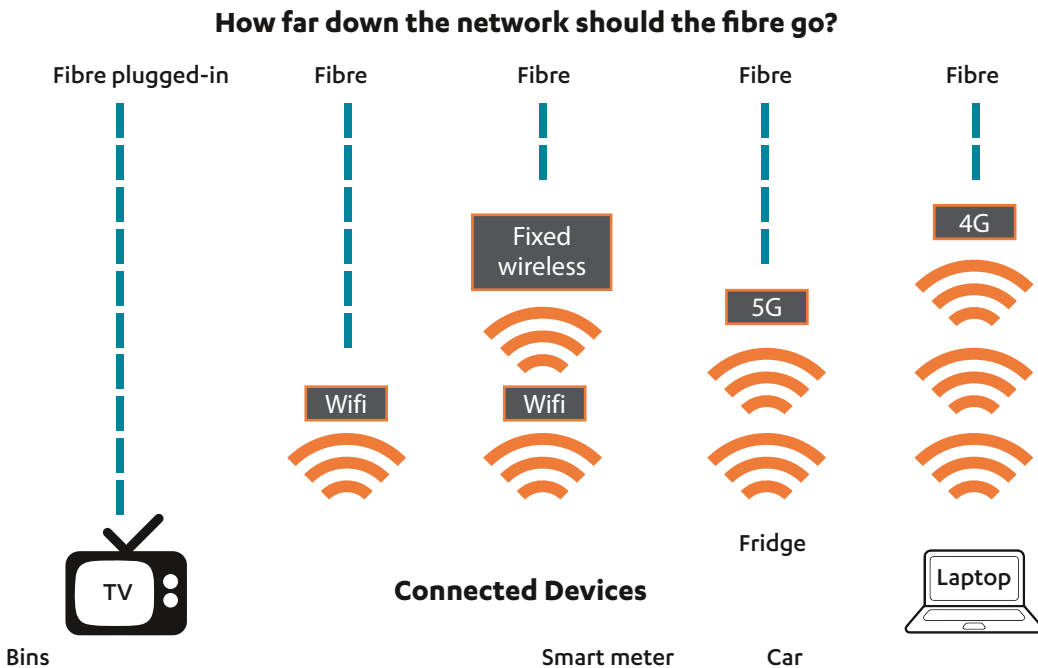
At the same time, mobile technology depends on networks of fixed fibre optic cables. Mobile 'cells', which transmit and receive data to and from mobile devices, connect to fixed fibre through which they are linked to the global internet ('backhaul'). The next generation of mobile technology (5G) will require a greater number of smaller 'cells' and will therefore require a denser network of fibre.⁶

It is also possible for Wi-Fi routers to connect to the mobile network, a technology known as ‘fixed wireless broadband’. This allows devices in the home or office to connect via the mobile network, but without themselves having a SIM card. Mobile reception can be accessed within a building where the signal is strongest, while devices within the building can connect to a Wi-Fi network.

Over the next few years, the UK will need substantial investment in digital infrastructure to retain its world leading digital economy and secure the benefits of new technologies for UK businesses and households. The UK needs to take an integrated view across both fixed and mobile infrastructure to maximise the benefits of this investment.

One thing is clear; an increasing amount of fibre optic cables will be needed to support both fixed and mobile networks. However, physically connecting every home and office will be expensive and take time to roll out.⁷ A focus on the deployment of full fibre networks risks the creation of a two-tier online community in the shorter term. This has been the case in Hull, where the incumbent operator chose to convert their network to full fibre straight away, rather than making incremental upgrades.⁸ This has delayed improvements for households that have yet to receive full fibre. An alternative strategy⁹ could be to deploy fibre to support future mobile technologies, then connect homes where and when it is economically viable.

Figure 1.1: Different types of fixed and mobile networks all use fibre and spectrum



‘Connected Future’ report

The Commission was asked in March 2016 to advise the Government on the steps the UK should take in order to become a world leader in the deployment of 5G mobile telecommunications networks, and on how to ensure the UK can take early advantage of the applications those networks could enable. The Commission published its report, *Connected Future*, in December 2016.

The Commission’s central finding was that mobile connectivity has become a necessity. It recommended the Government ensure that services are available wherever we live, work and travel, and that the UK’s roads, railways and city centres are ready for 5G.

‘Greater connectivity is inevitable and essential. The UK cannot be left behind.’

Overview of recommendations

- Responsibility for digital infrastructure should reside in one place in Government.
- Infrastructure should be in place for 5G mobile connectivity on motorways and key rail routes by 2025.
- Local Government should actively facilitate the deployment of mobile telecoms infrastructure.
- Development of meaningful performance metrics for the coverage people actually receive, and use these to determine a mobile Universal Service Obligation.
- A review of the existing regulatory regime to ensure it supports the sharing of telecoms infrastructure between different Mobile Network Operators.
- A review of how ‘spectrum’ (the range of mobile communication frequencies) is allocated to facilitate greater access, particularly for communities, local or regional networks and businesses requiring connectivity inside buildings.

Context

The work undertaken on digital communications for the Assessment directly builds on the Commission’s Connected Future report and the Government’s response. It will, however, have a broader and longer-term focus than the 5G study. The Assessment will consider fixed and satellite infrastructure networks, as well as mobile.

Digital infrastructure must be fit to enable the UK's smart future

The ability of infrastructure and appliances to connect digitally with each other directly, known as the 'internet of things', is expected to grow rapidly. A report from Cambridge Consultants, for Ofcom (the digital regulator), forecast that there will be 156 million 'internet of things' connections in 2024 – up from around 13.3 million today.¹⁰

The implications of digital technology for other infrastructure sectors are substantial. Digital infrastructure will underpin the greater use of sensors, automation, big data and cloud computing that will make the UK's infrastructure smarter. Smart homes, grids and cities with high levels of digital connectivity will become the norm. For example:

- Embedding sensors in structures such as bridges or wind turbines allows the collection of real-time data on asset condition and maintenance needs. This allows maintenance to be targeted more effectively, reducing failures and saving money. Data collected from sensors can help with the design of future infrastructure.
- Machine learning, combined with large quantities of data, can improve the working of complex systems such as infrastructure networks, for example calculating the optimal water pressure and controlling smart valves across a network of pipes to reduce leakage.
- Mobile phone apps, such as CityMapper, combine real time information of multiple transport modes to allow people to plan the most efficient route for their journey. Data on the trips people make could be used to optimise travel timetables and bus routes to create quicker, integrated and more convenient journeys.
- Smart appliances such as thermostats can be controlled remotely by users, to use less energy. With smart meters they will be able to interact directly with the grid, to manage peak demand more efficiently. For example, supermarket fridges can use more power to lower temperatures when electricity demand is low and then switch off at peak times, gradually returning to normal operating temperatures.

The UK's digital infrastructure needs to be ready to support these new demands from other infrastructure sectors. Given the geographically dispersed nature of infrastructure networks, this further reinforces the benefits of ubiquitous digital coverage.

Greater interactions between digital technology and other infrastructure sectors offer substantial scope for improvements in service levels, reliability and reduced costs.¹¹ However, they will also make other infrastructure – and indeed the economy in general – more reliant on digital services. That increases the risks that a failure in one part of the UK's infrastructure can cascade into a wider set of failures. Such cascading failures can be hard to address because they are often caused by the interactions of multiple factors, none of which individually would be serious.

Protection needs to be built into smart infrastructure from the outset to limit the impact of such failures, learning lessons from other sectors that have had to address similar problems, such as aerospace.

How things stand

Without further investment, the UK risks falling behind in the digital economy

The digital infrastructure environment is rapidly evolving and improving. UK regulation has delivered low consumer prices through competition.¹² This competition at the retail level has resulted in the UK having some of the lowest prices in Europe.¹³ It has also driven digital infrastructure improvements in areas where this is commercially viable. These improvements have enabled greater speeds for many UK consumers. UK businesses and consumers have taken advantage of this to build a world class digital economy.

However, the UK has invested less in ‘next generation’ infrastructure than many other comparable nations.¹⁴ In their Digital Communications Review, Ofcom, the digital regulator, announced a shift in their regulatory focus to increase investment in fibre networks.¹⁵ The UK’s international competitors are becoming increasingly ambitious. Whilst the UK fares favourably on its superfast broadband coverage, the UK’s competitors have moved onto ultrafast broadband.¹⁶ Whilst other countries prepare for 5G, the UK continues to lag behind in 4G availability.¹⁷

According to Ofcom, the UK ranked 17th out of 19 countries in 2015 for access to the internet by optical fibre connected directly to the premises – referred to as ‘full fibre’. In Japan and South Korea, over 70% of broadband connections are ‘full fibre’ compared to less than 2% in the UK.¹⁸ Ofcom ranked the UK 9th out of 18 comparator countries in 2015 for 4G population coverage.¹⁹

OpenSignal produce an alternative assessment of 4G availability, based on the proportion of time the users they sample have access to a particular network. On this basis, the UK scores 25th out of 34 OECD countries for 4G availability. South Korea has 96% availability for 4G mobile, compared to the UK’s 66%.²⁰

Many small and medium businesses also have their digital connectivity needs unmet. In 2016, 20% did not have access to broadband speeds of 30 Mbps (‘superfast’) and around 8% were unable to access speeds of 10 megabits per second (Mbps). Although coverage had improved on the previous year, these figures are still lower than for the population as a whole, suggesting small and medium sized businesses are missing out. Problems are not limited to rural areas: there is a particular problem in business parks, where only 67% had superfast broadband.²¹

‘We believe that the design, planning and introduction of Smart City technology across the UK is of great importance for ensuring that UK cities are a better place to live for citizens, while being more prosperous and secure.’

Fujitsu call for evidence response

Rural areas are particularly underserved

Underinvestment in the UK's digital infrastructure has left many areas underserved. Some areas experience extremely poor service. Other areas are making do with average service which should be better.²² This is no longer acceptable for the UK in the 21st century.

Rural areas are particularly underserved. The Commission's nationwide stakeholders have emphasised the issue of rural connectivity. Responses to the call for evidence indicate that the existing regime will not deliver what is needed, when it is needed. The UK will not be able to fully realise its digital ambitions whilst areas remain excluded. The development of smart infrastructure will further require connectivity to be ubiquitous.

The Superfast Cornwall programme is an example of how targeted intervention, from both private and public organisations, can improve rural connectivity.²³ During 2011-15 the programme connected over 12,100 businesses to superfast broadband:

- The Cornwall and Isles of Scilly region was previously severely underserved in terms of digital connectivity. The region was not considered an attractive commercial investment for telecoms operators, for reasons including its low population density and challenging geography.
- A joint investment between the EU and BT totalling £132 million has since provided superfast broadband to 95% of homes and businesses. Of these homes and businesses, 30% have access to ultrafast speeds through full fibre.

The Government announced in 2015 that it intends to give people the legal right to request a broadband connection that would deliver them a minimum speed of 10 Mbps by 2020 no matter where they lived, through a broadband Universal Service Obligation.²⁴ The Digital Economy Act 2017 legislates for this universal service. The minimum download speed of 10 Mbps will be reviewed by Ofcom once 75% of the population have subscribed to speeds of 30 Mbps ('superfast').²⁵

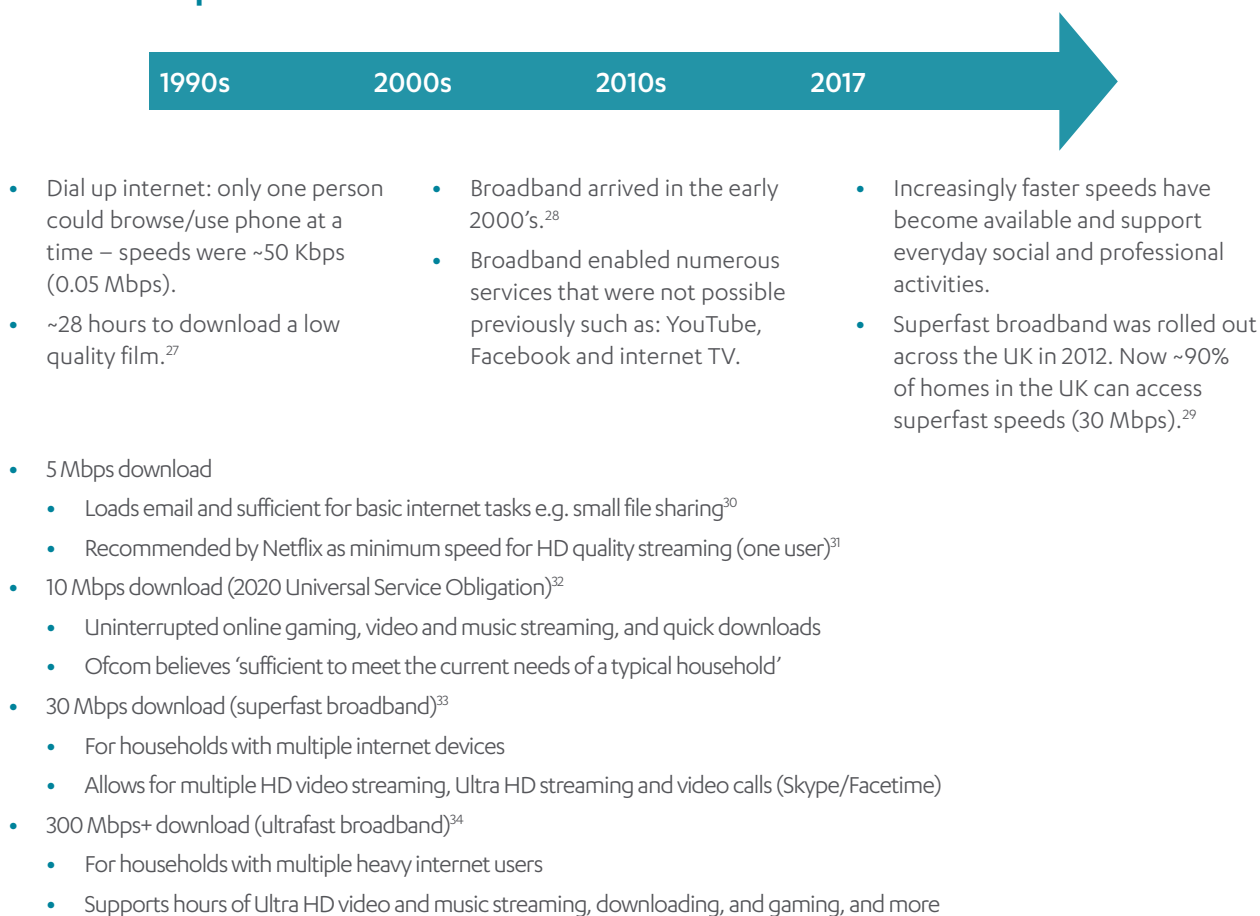
The Government launched a consultation on how to implement the Obligation in July 2017. Alongside this BT have offered to voluntarily provide this service across the country, which would largely be delivered by Openreach. The Government is considering both approaches.²⁶

'A collection of studies by Ofcom and others, suggest that in "non-competitive" areas ... the regulatory strategy driven by competition, has not delivered the same positive consumer outcomes, nor the necessary investment to maintain and upgrade network infrastructure to support a digital economy.'

The Scottish Futures Trust call for evidence response

The introduction of the Obligation (or an equivalent voluntary alternative) will go some way towards addressing a lack of connectivity in rural areas. The current regime will provide a basic level of service acceptable for today's standards. This is cheaper in the short term but fails as a long term solution. The digital communications sector moves quickly so the Obligation will need to be consistently reviewed and revised. Without a long term approach, a meaningful universal service will not be possible.

Internet speeds



Download speed is not the only metric which determines quality of connection. Upload speed, latency and reliability are increasingly important qualities for digital applications and services:

- Upload speeds are important for transferring files from a device to the internet, such as cloud computing and uploading pictures and videos.
- Latency is the delay in processing data. Connected and autonomous vehicles will require extremely low latency as delays could be life threatening.
- Reliability is important as society increasingly depends upon digital connectivity. Reliability means consistent quality of service.

Digital infrastructure needs a higher priority

Civil engineering works are the largest cost component of digital infrastructure installation. The process of obtaining planning permission and rights of way (“wayleaves”) for digital infrastructure can add significant costs and delays to network enhancements. Cutting these overhead costs would be one of the lowest cost ways of delivering better digital infrastructure quickly.³⁵ The Government made some changes to the Electronic Communications Code to improve the ease of rolling out digital infrastructure in 2016. However, many stakeholders consider that progress has been too slow, and that there is further scope for reform.

Reducing the need for construction work can also result in quicker and cheaper deployment. The resources saved from this can be spent instead on network quality and expansion, and making the UK’s infrastructure smart.

New infrastructure projects, varying from housing developments to electricity grid interconnectors, are being built with insufficient consideration to digital infrastructure. The construction work involved in these projects provides a unique opportunity to implement digital infrastructure at the same time.

The UK has not been taking advantage of its existing infrastructure. This includes both communications and non-communications, and both private and public sector assets. Using existing infrastructure can again drastically reduce the need for additional engineering work to be done.

Recent regulations should make it easier for telecom operators to make use of existing ‘ducts’ (the passageways already in buildings and underground that are used for communications networks and other purposes) and ‘telegraph’ poles.³⁶ Ofcom have recently consulted on proposals to enhance access to BT’s existing ducts and poles. Operators now have access to an online map of duct and pole locations.³⁷ However, a number of stakeholders have raised concerns that the quality of data available on the state of the assets is variable.

The Government has not prioritised the use of publicly owned property such as the national road and rail networks, which could support much better connectivity whilst travelling. The Commission’s *Connected Future* report on 5G mobile internet recommended using road and track-side infrastructure to enable significant improvements to mobile coverage along major routes. The Government has committed to exploring the commercial options for achieving this, reporting by the end of 2017.³⁸

‘It is vital that when the need for reform is identified it is accelerated to keep up with rapid changes in technology and usage. For example, reform to the Electronic Communications Code, currently being progressed as part of the Digital Economy Bill, was intended for 4G rollout. With 5G round in prospect it is important reforms put in place now are kept under review and adaptable to future demands.’

Mobile UK call for evidence response

‘Better use of existing national fibre networks e.g. Highways England, JANET and Network Rail ... improve choice and competition in our local connectivity market by making better links to national backhaul networks.’

West of England call for evidence response

Interdependent and complex infrastructure systems create new risks

Integration of digital technologies and other infrastructure sectors creates significant scope for improvements in efficiency and service quality, but also new risks. As infrastructure systems become more interdependent and complex, new ways to manage resilience are created but the risks from network disruption also become increasingly large. Even small failures in highly complex and interdependent systems can interact in unpredictable ways to create significant disruption.³⁹

Cascading failures occur where a fault or overload in one part of a network triggers a series of failures in connected parts of the system. For example, failures in power lines can cause loads to be transferred to connected lines. If the combined load exceeds the capacity of these lines, they in turn can fail, passing the combined load elsewhere onto the system and triggering a cascade of failures as each failure pushes more demands onto the remaining capacity.

System (or 'normal') accidents occur when a number of often small, unrelated, failures interact in unpredictable ways in complex, interdependent systems. In many complex systems, changes propagate rapidly from one part of the system to another. This is sometimes referred to as 'tight coupling'. In tightly coupled systems, failures are transmitted rapidly from one part of the system to others. Multiple small failures can interact with and amplify one another, creating major problems before operators can understand what is happening.

Resilience to system accidents will become more important as the UK increasingly relies on smart infrastructure systems. Smart systems are more efficient, but also more complex and more tightly coupled. Failures in digital infrastructure will in future affect other infrastructure systems.

Given how dependent modern life is on infrastructure services, the risk of multiple interacting failures is a serious one. The Royal Academy of Engineering studied the impact of Storm Desmond in Lancaster. In 2015 a flood at an electricity substation led to no internet, mobile phones, contactless payments, lifts or petrol pumps.⁴⁰

Resilience is not a new problem to those involved in infrastructure. The UK has an existing world class and resilient infrastructure system. Problems of cascading failures and system accidents arise in other industries, such as aviation or petrochemicals. Industry and Government can take advantage of their years of experience. Satellite communications may provide a complementary system to fixed and mobile networks that would increase resilience. The UK must apply the lessons elsewhere learnt to this latest challenge of digital resilience. There is an opportunity to help shape the development of these digitally-connected infrastructure systems at an early stage to make sure resilience is embedded.

Digital communications networks also need to be resilient to many other kinds of threats, both human and environmental. This includes malicious acts, accidents and climate change. Other bodies, such as the Centre for the Protection of National Infrastructure are already focused on these broader issues. The Commission will collaborate closely with them, but is keen to avoid overlaps.

The Commission's priorities

Technology

The UK needs an integrated strategy for fixed and mobile networks. The objective should be to capture fully all the connectivity benefits from any digital infrastructure investment. This includes the future connectivity needs of consumers and businesses. It also includes smart infrastructure systems. For instance, any fibre deployment aided by state intervention should be planned with the likely needs of 5G deployment in mind.

Faced with uncertain future demand and rapid technological change, the primary strategy by industry and Government to date has been to make incremental improvements to the UK's existing infrastructure.⁴¹ This is beginning to change, with Ofcom's Strategic Review of Digital Communications proposing a greater emphasis on fibre roll-out. The Government have announced a £400 million digital infrastructure investment fund.

Fibre to the home or business – 'full fibre' – is considered to be the best technology available.⁴² It can provide the highest quality of service in terms of speed and reliability, but it comes at a high cost, predominantly because of the need for civil engineering to lay the fibre (fibre itself is not expensive). Once deployed however, there is a reduced need for further intervention in the network.

The extent, timing and funding of fibre optic roll-out across the country is not clear at this stage. Openreach (which owns the copper network, originally designed for telephones) is pursuing a strategy based on a mix of full fibre and the 'G.Fast' technology, which continues to use copper connections.⁴³ Virgin Media (which owns a parallel network, primarily based on coaxial cable originally designed for cable TV) is planning to extend its network to cover an additional 4 million UK premises, of which around half will be full fibre connections.⁴⁴ A range of smaller providers are also delivering full fibre, including at city scale in York and Hull.⁴⁵ Plans for further expansion are fundamentally dependent on forecasts for future demand, which are very uncertain.⁴⁶

'5G and 'full-fibre' are effectively two aspects of the same integrated network infrastructure that the UK needs. Supporting the suite of technologies represented by 5G will require dense fibre penetration, particularly in cities.'

Manchester Digital call for evidence response

It is clear that more fibre will be needed. The next generation of mobile technology, 5G, will require a large number of small ‘cells’ and a dense fibre network to connect to. Future demand from households and businesses for ever greater speed and reliability will also require further investment in fibre networks.⁴⁷

However, physically connecting fibre to every home and office is not necessarily inevitable in the long term. Many devices already connect in the first instance via the radio spectrum, through Wi-Fi or Bluetooth. Deploying fibre to support future mobile technologies, whether 5G or its successors, then connecting homes where and when economically viable, might offer an alternative strategy.⁴⁸ Devices within homes and offices might then connect directly to 5G, or via a ‘fixed wireless broadband’ device, which would provide Wi-Fi within the building and connect via 5G rather than needing fibre within the building.

The cost implications of shifting the fibre and wireless balance could be significant, although some stakeholders have argued that there is scope to lower fibre costs substantially. Digging up roads and front gardens can be expensive. Google Fiber in the US have moved away from deploying fibre to every home and towards using wireless connections to provide properties with connectivity. This is due to the high cost and length of time required to physically connect each home.⁴⁹

Other technologies take advantage of existing infrastructure, such as copper (the traditional telephone network) and coaxial cable (cable television networks). Technology using these networks is not standing still, with ‘G.Fast’ for copper and ‘DOCSIS 3.1’ for cable enabling faster connections. This approach is cheaper than deploying a new full fibre network, and could provide ‘ultrafast’ speeds. Operators can invest in incremental improvements to the existing network, without incurring the civil engineering costs involved in rolling out fibre networks. Improvements in data compression also mean that more information can be transmitted or received with existing physical capacity.

This means that improvements can be delivered faster and at less cost. But it delays investment in fibre networks, creating a risk that the UK is unready for new applications that may emerge and need the capability that fibre offers. A key factor is the length of time it would take to deploy a fibre network in response to such potential applications. And while these technologies improve some aspects of connectivity – particularly download speeds – they do not offer all the benefits of full fibre.

To inform its recommendations, the Commission has engaged advisors to take forward detailed cost and benefit analysis of the following digital infrastructure options:

- Fibre to the home
- Fibre to 5G
- The copper-based technology 'G.fast'
- The cable-based technology 'DOCSIS 3.1'
- Fixed wireless access – a wireless connection from one fixed location to another

The cost analysis will quantify both deployment and operating costs of the various infrastructure options. The benefit analysis will evaluate the known and reasonably foreseeable benefits. It will also conduct a historical analysis to identify what drove patterns of adoption of earlier digital technologies by people and businesses. Predicting demand for digital technologies is difficult because new uses can arise and drive previously unforeseen demand. For example, social media was not predicted at the time when the first data enabled phones became available but has been a key driver of demand for smartphone data capacity.

While this work focuses on fixed digital infrastructure options, it will also consider benefits for mobile networks given the common fibre component for both. The Commission will publish both reports before the end of 2017. This will inform the recommendations in the final National Infrastructure Assessment.

The Commission has already started a dedicated study on the opportunities presented by new technology for making the UK's infrastructure more productive. The Commission is due to report its recommendations to Government by the end of 2017. The study is exploring which emerging technologies have the greatest potential to improve the effectiveness of the UK's infrastructure and its contribution to economic productivity.⁴⁰ The study is particularly focussed on data-based technologies which will be highly dependent on digital connectivity. The findings of the study will inform work on the Assessment.

International approaches to full fibre rollout

There are a range of approaches to the deployment of full fibre. Some countries, such as Australia, New Zealand and South Korea, have decided to directly subsidise fibre networks. Many EU countries, such as Spain, the UK and Lithuania, have tried to incentivise deployment through regulation, with varying results. Others, such as the USA, have promoted infrastructure competition, which results in multiple networks being built.

Australia

In 2010, the Australian Government created a national broadband network, taking fixed digital infrastructure into state control. This was originally envisaged as a strategy to provide full fibre to 93% of the country.⁵¹

Following a change of Government in 2013, the full fibre plans were mostly scrapped. A cost-benefit analysis by the new Government supported its decision to adopt a mixed technology approach instead. This includes 22% full fibre connections alongside a mix of other, less costly technologies.⁵²

New Zealand

In 2009, the New Zealand Government launched an initiative to provide full fibre to 84% of the population by the end of 2024.⁵³ The Government is investing \$2 billion (NZD) in the long-term infrastructure build-out.⁴⁵ To deliver this the Government is funding a single full fibre network, managed through a series of public and private contracts.⁴⁶ In parallel, a 'Rural Broadband Initiative' is providing improved broadband to over 300,000 homes and businesses in rural communities.⁵⁶ Uptake is currently at 28% for ultrafast broadband.⁵⁷

The EU

The EU has primarily focussed on improving access to existing infrastructure, such as ducts, poles and in-building wiring, which is usually owned by the incumbent. Infrastructure access results in competitive offers for consumers as the barriers to provide broadband services are reduced.⁴⁸

Lithuania and Spain are successful examples of this model, with over 60% coverage of fibre to the premises.⁴⁹ After access to their incumbents' passive infrastructure was opened up, competitors began to deploy fibre. This created competitive pressure and resulted in the incumbents deploying their own. However, this model is not always successful, or suited to each individual country.

USA

The USA has focussed on end-to-end competition, due to the parallel cable and copper networks which already existed almost nationwide. This has resulted in greater fibre deployment, but less choice at the retail level than the UK. Prices are also higher.⁶⁰

Funding

The UK needs a world class digital infrastructure network. The UK's digital ambitions should not be constrained by sub-par infrastructure assets. Most investment in digital infrastructure is delivered by the private sector, funded by consumers.⁶¹ The level of investment therefore depends on expectations for consumer demand and the degree and nature of competition in the digital infrastructure sector. The Government has also provided some funding. In some cases, it may be necessary or desirable for Government to fund investment that cannot generate a commercial return.

The combination of competition policy and any direct Government support needs to deliver the long-term investment in digital infrastructure that the UK needs, both 'next generation' technologies and universal access. To date, the UK's framework has delivered low consumer prices and incremental network upgrades, but much lower levels of full fibre and 4G provision than many of the UK's competitors.

Competition is regulated by Ofcom. Ofcom have to operate within the objectives set out in the Communications Act 2003, which is itself ultimately based on European law. This specifies that Ofcom's primary objectives are to further the interests of:

- citizens in relation to communications matters; and
- consumers in relevant markets, where appropriate by promoting competition.⁶²

Ofcom must also have regard to the desirability of encouraging:

- investment and innovation in relevant markets; and
- the availability and use of high speed data transfer services throughout the United Kingdom.

With Britain leaving the European Union, there is scope to reconsider the framework within which the regulator, Ofcom, is required to operate.⁶³ Internationally, a range of regulatory approaches have been tried and, in part at least, these differences do appear to have impacted on levels of investment.⁶⁴ One mechanism for any changes might be the Digital Economy Act 2017, which provides the scope for the Government to set out its strategic priorities for telecommunications.⁶⁵ Ofcom would then have to have regard to these priorities.

Digital infrastructure is much more costly to deploy in rural rather than urban areas, which creates funding challenges.⁶⁶ Bespoke solutions will be required to deliver the connectivity needed. This could include options such as targeted localised strategies. Examples include locally funded tower or duct assets to ensure rural areas have the basic passive infrastructure in place.

The Government must maintain a long-term view to ensure that the Universal Service Obligation meets not just the needs of today, but will also deliver outcomes that meet the needs of the future. This will require ubiquitous connectivity that keeps pace with the requirements of participating in an increasingly digital society. The costs of the universal service are shared across consumers. In a competitive market, there are limits to how high these costs can rise.

Some countries have made greater use of Government subsidy than the UK, but with mixed results. Subsidies can be effective at ensuring provision in areas where it would not be commercially viable. However, they can also crowd out private investment and potentially delay investments that would otherwise have happened.

In the next stage of the Assessment, the Commission will consider whether the regulatory framework is sufficiently focussed on investment and how to ensure rural areas do not continue to lose out.

Making it happen

The Government must act as a digital champion, ensuring the UK has the connectivity it needs. In its *Connected Future* report, the Commission recommended that ‘ultimate Government responsibility for digital infrastructure should reside in one place under a single cabinet minister with the authority to shape policy and delivery across Government, ensuring that it delivers the Government’s overarching digital strategy’.⁶⁷

A coordinated approach is essential. At present, digital infrastructure decisions are fragmented and entwined with the wider policy interests of numerous Government departments and agencies.⁶⁸ Digital is often an add-on and so is too easily deprioritised. A single digital champion within Government should hold relevant departments and agencies to account to ensure the provision of digital infrastructure in the delivery of infrastructure programmes.

Lack of connectivity on transport networks is a clear example of the Government’s co-ordination failure. Digital communications are inevitably not the core objective for transport projects. However, connectivity on transport is now essential. As set out in chapter 5, connectivity is critical to realise the benefits of connected vehicles. Lack of connectivity on rail is holding back productivity. The Government must act in a coordinated manner to solve this. The Commission’s *Connected Future* report made the recommendation to have the necessary infrastructure in place for 5G on motorways and rail routes by 2025.

The Government published a ‘5G Strategy for the UK’ in response to *Connected Future* in March 2017. This commits to establishing a new centre for 5G expertise in the Department for Digital, Culture, Media and Sport and allocates £16 million for a national 5G Innovation Network to trial and demonstrate 5G applications. Further action is promised by the end of 2017, including setting out whether the Government believes further changes are needed to the planning and regulatory system and setting out what the Government see as the essential elements of high quality coverage and how this will be achieved no later than 2025.⁶⁰

Local Government must also be more proactive. Digital communications bring significant benefits to local areas. Local authorities have to do more to encourage the deployment of infrastructure. This includes facilitating planning permission for the investment the UK needs, without long delays. The planning process can be very time consuming and costly for operators. Applications are required for every individual site, rather than on a network basis like other infrastructure. Local authorities could play a more proactive role in making the process easier through coordinated connectivity plans. This will be increasingly critical as the UK moves from 4G to 5G due to the need to deploy small cells on a scale not previously seen in the UK.⁷⁰ Changes to planning may be needed to facilitate rapid approval for the digital infrastructure the UK needs. The Government has consulted on whether local authorities in England should be required to have planning policies setting out how high quality digital infrastructure would be delivered in their areas.⁷¹

‘The current fragmented nature of planning systems – and the decision-making within that – will make it incredibly difficult to roll out the infrastructure needed to provide a ubiquitous, high-quality and reliable mobile service. Scale is needed for such decision making that reflects the nature and geographic spread of the investment.’

Three call for evidence response

Policy on spectrum allocation must reflect the increasing integration of fixed and mobile technologies to be fit for the future. The radio spectrum is used for mobile and wireless connectivity but it is a finite resource.⁷² Bands are allocated to users such as the mobile operators by Ofcom to ensure the spectrum is efficiently used and to avoid interference between users. Ofcom are currently reviewing allocation of spectrum, and are due to report back to Government at the end of 2017.⁷³

Development of digital infrastructure can be improved by increasing transparency and information sharing, for instance enabling improved mapping of infrastructure assets. The Commission’s New Technology study is considering the challenges associated with data sharing and management in infrastructure sectors, including data on commercial and critical assets, and how these can be addressed. The study’s conclusions will inform the final National Infrastructure Assessment.

Developing more resilient smart systems

To address the challenges of resilience, the Commission has engaged external advisers to provide research on how smart infrastructure systems can be made more resilient to the risks of system accidents. This work will consider what options exist to reduce risk at an organisational level. This includes addressing practical challenges where ownership and management are split through multiple operators or agencies, across both the public and private sectors. This research will inform the Commission’s recommendations and identify areas in which further research is necessary.

Evidence from other industries that face similar problems suggest three key areas for consideration. The first is corporate and organisational best practice. This includes how lines of responsibility and accountability are made clear and how accidents are reported and investigated effectively. The second is the decision-making process.

Measures to address emerging risks must be considered at a sufficiently early stage. The third is how improvements can be implemented, given the fragmented ownership, responsibility and accountability for infrastructure assets and services.⁷⁴

More stringent safeguards may also be required for some of the infrastructure systems that are most critical to the effective functioning of the wider economy and society. In some cases, it may be necessary for critical systems to remain disconnected from digital networks to ensure resilience.

In the next stage of the Assessment, the Commission will consider how to ensure smart infrastructure systems are resilient. Once the first Assessment is complete, there may be a case for the Commission to carry out a more in-depth analysis of resilience as a whole, working with key stakeholders.

The Commission's vision

Meeting the Commission's vision would see the UK have:

- The Commission's vision for the UK is simple and ambitious: world class digital connectivity that is seamless, ubiquitous, reliable and resilient.
- This will promote leading-edge applications at an early date, including for other infrastructure systems. Networks of sensors, smart appliances and the combination of vastly improved data and machine learning will facilitate ease of use, lower cost and increase efficiency.

Questions for consultation

The UK has invested less in 'next generation' infrastructure than many other advanced economies.

- 5) **What changes are needed to the regulatory framework or role of Government to ensure the UK invests for the long term in globally competitive digital infrastructure?**

Fixed and mobile networks are converging. Both the technology itself and its uses are driving this increasing convergence.

- 6) **What are the implications for digital infrastructure of increasing fixed and mobile convergence? What are the relative merits of adding more fibre incrementally over time compared to pursuing a comprehensive fibre to the premises strategy?**

Connectivity has become a necessity where people live work and travel, in both urban and rural areas. Rural areas however continue to be excluded. The Commission want to know what role central and local Government should play to ensure ubiquitous connectivity.

- 7) What are the key factors including planning, coordination and funding, which would encourage the commercial deployment of ubiquitous connectivity (including, but not only, in rural areas)? How can Government, Ofcom and the industry ensure this keeps pace with an increasingly digital society?**

As infrastructure systems become more smart, complex and interdependent, the potential for unintended interactions in the system increases. As a result, the likelihood of accidents also increases. Greater use of digital connectivity can make the impact of these 'system accidents' (unanticipated interactions of multiple failures in complex, interconnected systems) accidents more damaging than ever before.

- 8) How can the risks of 'system accidents' be mitigated when deploying smart infrastructure?**

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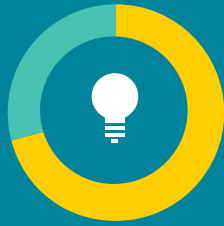
2. CONNECTED, LIVEABLE CITY-REGIONS



CITIES ARE THE HEART OF THE MODERN ECONOMY:

71%

of knowledge economy jobs are in cities



54%

of the UK population live in cities



BUT – THERE ARE BARRIERS TO THEIR PROGRESS:

House prices

in cities have risen over the past decade – in some areas by as much as 50% – pricing talented workers out



Rail networks are overcrowded

with more passengers standing – around 60% more people commute by rail than in 2005



Congestion

makes road journeys slower and less predictable – traffic delays on urban roads are more than three times higher than on rural roads

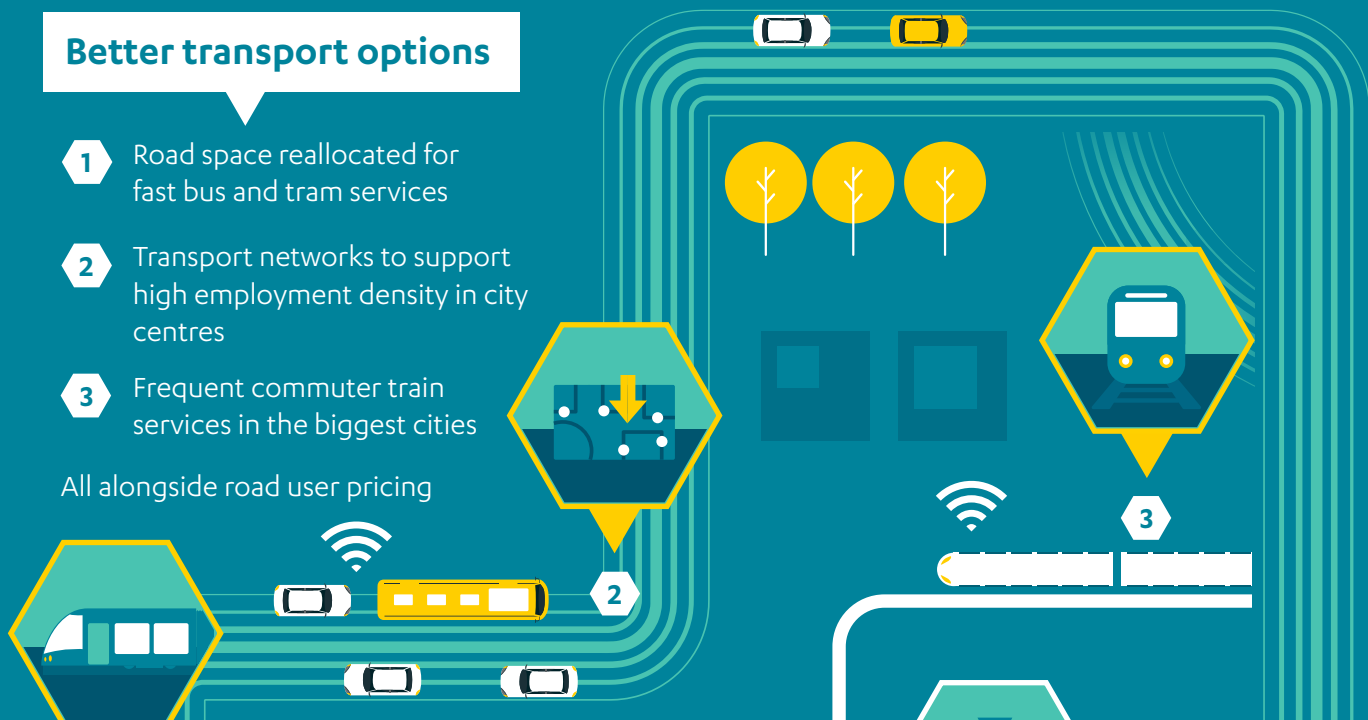
WE NEED MORE PEOPLE TO BE ABLE TO LIVE AND WORK IN OUR CITIES

A Better Future

Better transport options

- 1 Road space reallocated for fast bus and tram services
- 2 Transport networks to support high employment density in city centres
- 3 Frequent commuter train services in the biggest cities

All alongside road user pricing



Well-designed cities

- 4 Long-term funding for city strategies, supporting housing and economic growth
- 5 Green spaces, more people able to walk and cycle, cultural, leisure and social activities
- 6 City leaders creating integrated plans for housing and transport, offering more homes in and around cities

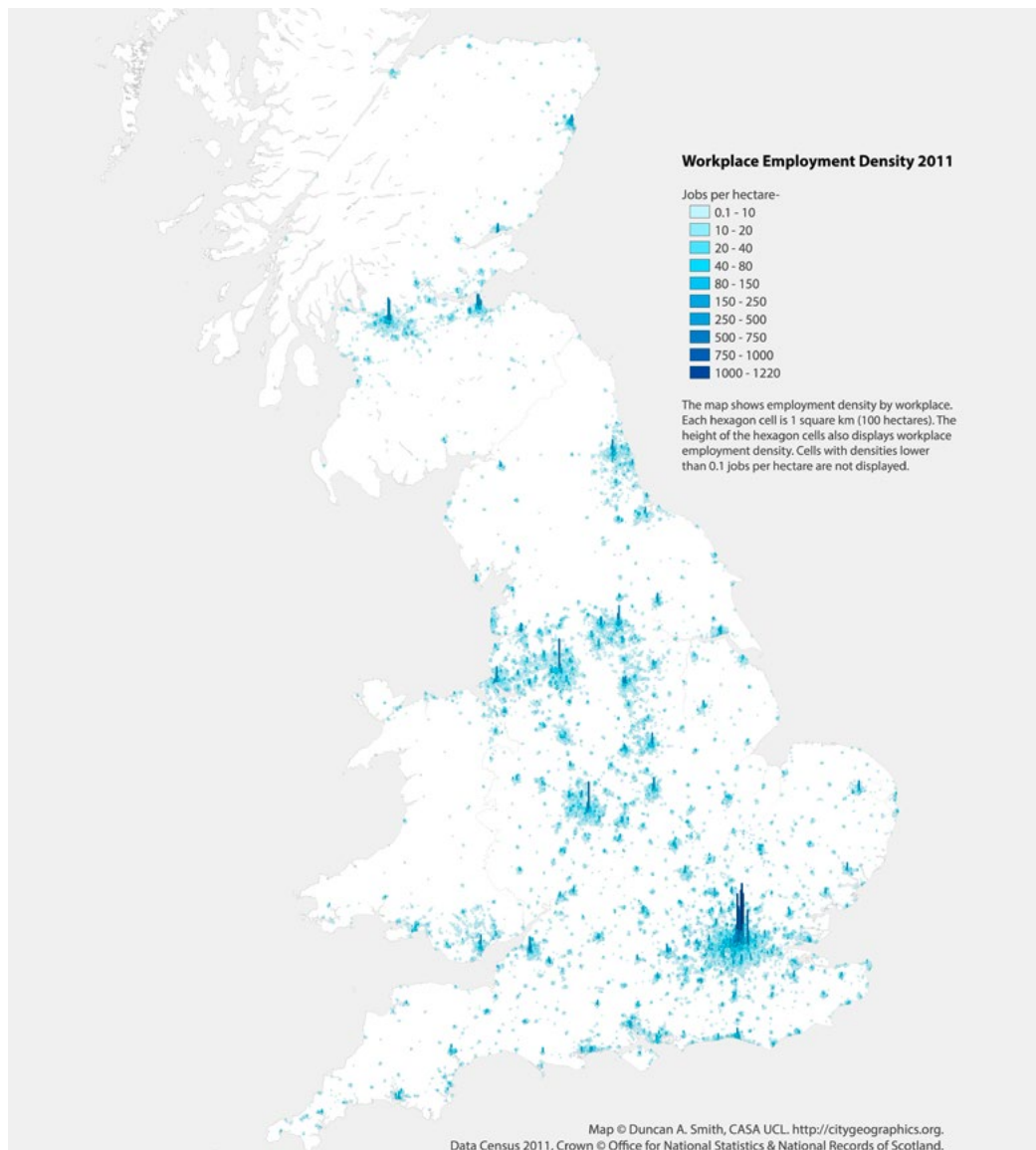


Sources: Centre for Cities, HM Land Registry, DfT

The need for action

Cities are the country's main engine for economic activity, employment and growth. 60% of jobs are in cities.¹ Cities are especially important for the UK's growing strength in highly skilled business services. 71% of jobs in knowledge-intensive service industries are in cities, and 74% of the UK's services exports come from cities.² Cities are a hub for wider city-regions, delivering employment and a range of specialist services that can only be provided with the population density cities offer. The Government's Industrial Strategy commits to using additional infrastructure funding to unlock growth in areas where connectivity is holding it back.³

Figure 2.1: Workplace Employment Density in Great Britain⁴



Large populations and business density in cities enable people to interact rapidly, efficiently and constantly, sharing their knowledge and resources and supporting innovation. This is especially important for highly skilled and well-paid jobs in knowledge-intensive services. Other factors – especially skill levels – also affect productivity. But overall, higher concentrations of employment lead to higher productivity and wages.⁵ Enabling these concentrations is one of the key ways in which infrastructure can support the economy. Living and working in cities also provides access to a wider range of social connections and cultural activities.

The Commission has an objective to support sustainable economic growth in all regions of the UK. Ensuring that urban areas across the country, including the major cities in the Midlands and the North, benefit from improved infrastructure systems will play an important role in achieving this.

The benefits of living and working in cities, along with the growing importance of knowledge-intensive services in the economy, have seen cities grow. This follows an earlier period of declining population in cities. Between 2005 and 2015 London's population grew by 15%, and other city regions such as Manchester, Sheffield, Leeds, Birmingham and Bristol grew by more than 6%.⁶ Growth has been even faster in city centres, reaching nearly 16% in central Manchester, 11% in Bristol and 10% in Birmingham.⁷

The Office for National Statistics' central projection is for the population of London to grow by more than 10% per decade to 2039, with other major cities growing at close to 6% per decade.⁸ The Commission has also produced a scenario in which population growth is distributed away from London, based on historic rates of house building. This would see the population of London grow by 7% per decade.⁹

People's ability to choose to work in cities and live in or around them is becoming constrained by limits to the capacity of infrastructure. Higher growth in the population and the economy means greater demand on city infrastructure than elsewhere in the country.

Congestion on city roads means travelling takes much longer and journey times are less predictable. Congestion on rail services means increasing numbers of peak-time passengers having to stand. Rising demand for city living, combined with restricted house building, drives up house prices. Over the last decade, house prices in city centres have increased more than in surrounding areas in most major cities including London, Manchester, Birmingham, Sheffield, Leeds and Bristol.¹⁰ In some smaller cities such as Oxford, Cambridge and Reading, as well as some central London boroughs, prices have increased more than 50%.¹¹

Congestion and high prices are drawbacks to living and working in cities. But people and firms continue to move to them, demonstrating their economic and social attractiveness. Urban infrastructure therefore needs to make it easier for more businesses to choose to locate in cities and for people to be able to live in or around them to access the good jobs they can create.

This will mean increasing the capacity and improving the reach of the transport networks serving major cities, so that more people can travel efficiently into their central districts. And it will mean making sure that infrastructure is used effectively to join up new housing development with jobs and other opportunities in city centres.

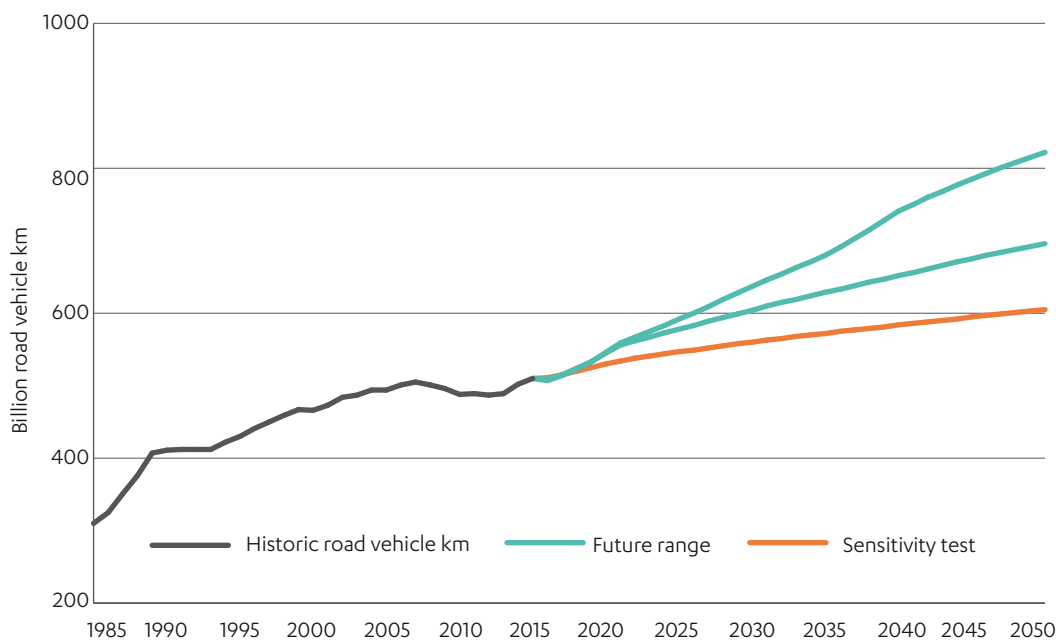
Urban infrastructure needs to promote a better quality of life. Cities with higher population densities can be thriving places with a high quality of life, but only if the right infrastructure decisions are made to support this. Infrastructure needs to protect city air from harmful pollution and support high-quality, green public spaces for meeting, shopping and relaxing. Cities need state-of-the-art digital infrastructure (see Chapter 1), low cost, low carbon energy (see Chapter 4) and protection from floods and drought (see Chapter 6) to support fast rising populations.

Connections between cities

The Commission's modelling projects that, for Great Britain as a whole, road usage will grow by between 37-61 % by 2050 and rail use by 12-43%.¹²

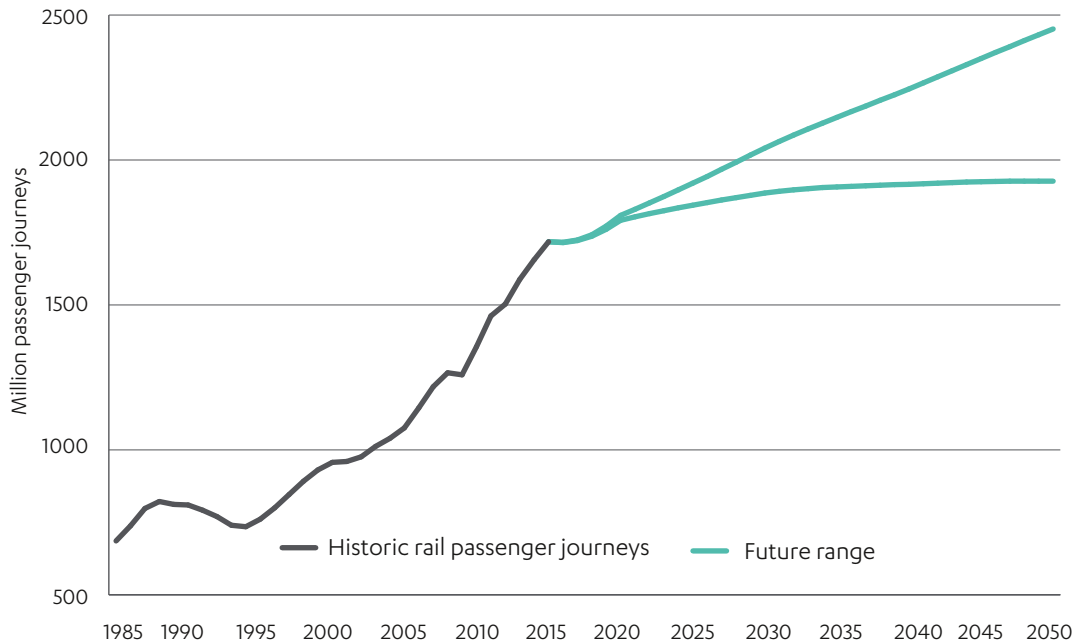
Figure 2.2: Travel demand¹³

Road



Note: The orange line corresponds to a scenario where road travel is unresponsive to changes in income. It represents the uncertainty around the relationship between future road travel growth and income growth (sometimes referred to as the "peak car" debate).

Rail



As cities grow, there is an increasing need for them to be well connected to other places. Connections between cities and with international gateways support the economy by linking businesses with customers and supply chains, as well as enabling exports of British-made goods and services to reach international markets. They also support social and leisure activities.

Growing cities contribute to pressure on these longer-distance networks, especially by giving rise to congestion on journeys into and out of cities, and on journeys which pass near to cities: witness the M25, M6 Birmingham box and the rail termini and major stations including Manchester Piccadilly, Birmingham New St, Clapham Junction, Waterloo, Victoria and Euston. The growing importance of cities also supports the case for improved direct and fast connections between them.

Most road and rail infrastructure is paid for by the public sector. With constrained public finances, projects that create the highest value need to be prioritised. However, it is important that the individual economic needs and potential of different cities and regions are taken into account when considering the case for investment. The emphasis should be on cities getting the right level of funding to meet their specific infrastructure needs in order to support economic growth and productivity across all the regions of the UK.

In some cases, property values can rise significantly around new or enhanced transport hubs, leading to investments paid for by taxpayers generating windfalls for property owners. Taxing a small proportion of this increased value could provide a potential new source of revenue towards the costs of valuable infrastructure projects.

How things stand

Metro, tram and rail projects are dramatically increasing the capacity and convenience of city public transport systems, including Manchester Metrolink, Midlands Metro and Crossrail in London. New cycleways, particularly London’s “cycle superhighways” and segregated cycle routes, are also transforming urban transport by providing green, clean and healthy transport options. New public transport, cycling and walking infrastructure is vital to tackling urban congestion and promoting healthy growth. Every city should have credible plans for such “next generation” projects and a priority of the National Infrastructure Commission is to work with mayors and leaders of councils to identify and evaluate key projects for inclusion in the 2018 National Infrastructure Assessment.

The capacity of city road networks cannot easily or sustainably be expanded, however, which risks limiting the ability of successful cities to grow and thrive. Within cities, it is generally problematic, if not impossible, to build more major road capacity. Space for additional transport corridors is both costly and heavily limited by existing buildings. Tunnelling can be an option, but is also very expensive. In most cases, using the existing road space more efficiently is the only realistic and sustainable option.

Beyond inner London, the car is still the predominant form of transport for getting to work in the UK’s cities. At least 70% of workers travel to work by car in the city regions around Manchester, Liverpool, Leeds, Sheffield, Newcastle, and Birmingham.¹⁴ UK cities such as Manchester and Birmingham have a much higher proportion of journeys in cars than comparable cities across Europe.¹⁵

Figure 2.3: Usual method of travel to work by location of workplace¹⁶

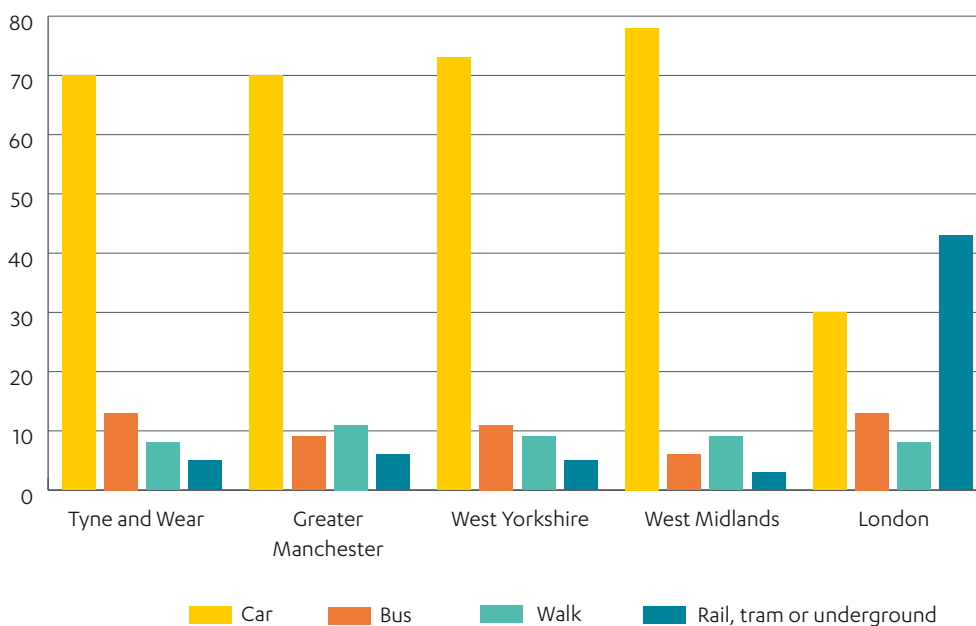


Figure 2.4: Transport mode share in European metropolitan areas¹⁷



Congestion blights most of our cities and major urban areas. Cities from Southampton and Bristol to Liverpool and Manchester see congestion delays of more than 80 seconds per mile driven on city centre A roads.¹⁸ This compares to 46 seconds per mile on average nationally.¹⁹ Congestion has been getting worse in recent years, with average peak-time speeds on local A roads slowing since 2012 in nearly all major cities.²⁰ These delays make travel in cities unattractive, and reduce the number of people who can work in a city centre, where they would be more productive.

Effective long-term policy to manage congestion will need to incorporate pricing for roads (see Chapter 5), as part of a strategy including enhanced city public transport and safe infrastructure for cycling and walking. The London Congestion Charge successfully reduced the volume of targeted traffic entering London, allowing more road space to be allocated for bus lanes and cycling as well as generating extra revenue for public transport. Durham (which has a road user charge zone) and Nottingham (which has a workplace parking levy) also make use of pricing. Low emission charging zones, which London is again leading, have similar effects. Elsewhere, however, the congestion pricing debate has stalled while congestion continues to increase.

The new landscape of city leadership, including metro mayors, combined with changing forms of mobility and ownership offer a new opportunity to open a debate about the benefits of congestion and pollution pricing. The introduction of more pricing schemes in cities could allow different approaches to be tested and eventually pave the way for a nationwide scheme in the longer term. Developing standards in payment systems and forward-funding the local infrastructure could be a positive role for central Government.

Making best use of limited road space

In cities, where there is high demand and limited space, public transport also enables better use of limited space in transport corridors, as shown in Table 2.1.

Table 2.1: Maximum system capacity of different forms of public transport²¹

Technology	Maximum system capacity (passengers per hour per direction)
Standard bus	2,500–4,000
Busway	4,000–6,000
Guided bus	4,000–6,000
Tram/Light rail	12,000–18,000
Heavy rail	10,000–30,000

Buses are the most widely used form of public transport, even in major cities. However without sufficient priority over cars, bus journey times can be slow. Urban bus speeds have been steadily reducing over time. In most of the UK buses are insufficiently integrated into wider city transport networks. Buses remain an unattractive option to many, with passenger numbers in cities outside London falling by nearly 10% over the last ten years, even as city populations have been increasing.²²

‘Bus rapid transport, when properly implemented, offers urban rail-type speed and reliability at lower capital cost.’

Professor David Metz
call for evidence response

Tram and light rail networks offer greater capacity and have already been a success in some of the largest cities, with passenger numbers increasing between 2005-16 by 72% in Manchester, 24% in Nottingham and 13% in Tyne and Wear.²³

Cities also make use of the national rail network for commuting, with rail passenger numbers growing by 60% between 2005 and 2016.²⁴ While most rail commuting continues to be focused around London, some other cities have also seen significant increases in demand for rail travel.²⁵

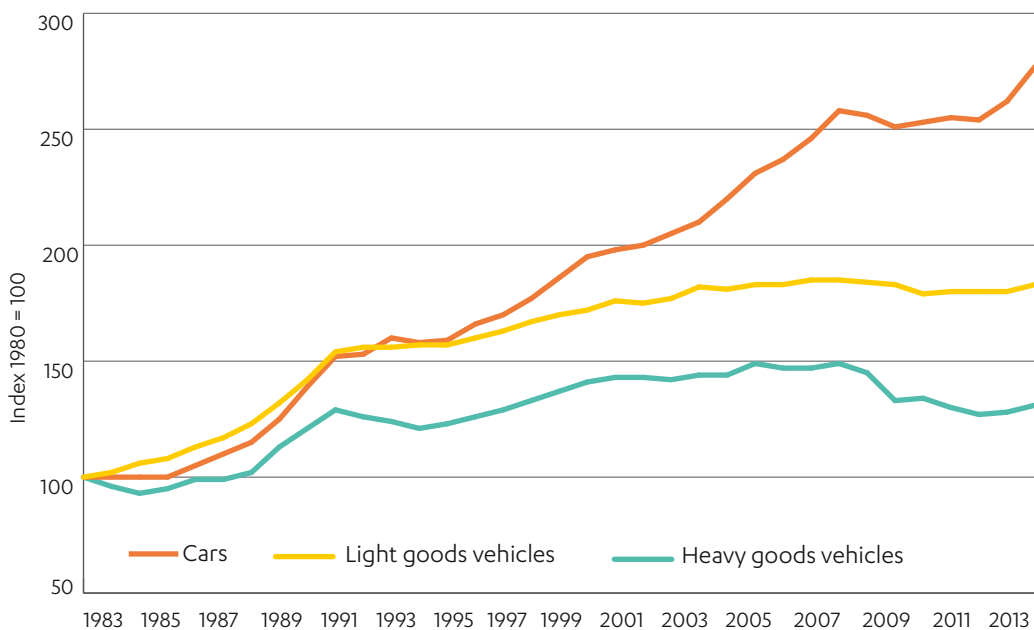
Despite increased capacity, this growth in passenger numbers has meant overcrowding on rail services. Overcrowding during peak times in London has increased by 45% between 2011 and 2016, meaning that almost a quarter of passengers now have to stand in the morning peak.²⁶ Rail overcrowding also occurs in other major cities, with 14-16% of morning peak time passengers having to stand in Manchester, Birmingham and Leeds.²⁷

Urban freight is too often overlooked

Freight and service vans need to be able to move around within cities. A lack of capacity on urban networks adds costs and delays which are ultimately passed on to firms and consumers. Over the years, city transport plans have overlooked freight activities.²⁸ Urban freight policies are often inconsistent across local authority boundaries, which causes additional costs for freight companies who need to operate across them. Rising urban property prices have pushed freight handling facilities further from city centres, requiring longer journeys to and from depots. A lack of integration between land use planning and transport means that the impact on congestion is not properly taken into account.

Growth in van travel contributes to congestion (see Figure 2.5). Though online shopping is growing, parcel and courier deliveries make up a small proportion of van trips. Construction, servicing, and delivery of food, drink and general freight are the main freight activities.²⁹

Figure 2.5: Vehicle kilometres travelled in Britain 1980 – 2014 (Index 1980 = 100)³⁰



‘Investment in the Strategic Road Network is critical to support access but it is the end of the journey and entry to the city that takes a disproportionate amount of time, with the same routes used by commuters, business (including freight) and visitors.’

Portsmouth City Council call for evidence response

International urban transport success

Many European cities have demonstrated that it is possible to improve the effectiveness of their transport networks by supporting better public transport and opportunities for cycling and walking. In the Manchester and Birmingham city regions public transport, cycling and walking account for around a third of all journeys, compared to 56% in Lyon and 68% in Bilbao.³¹

Vienna

The regional transport authority Vienna Verkehrsverbund oversees a network of underground metro, tram and bus services, integrated with regional rail services. Political prioritisation of public transport has seen five new metro lines constructed since 1969, with restrictions on parking and driving to encourage people to use public transport. More recently measures have been taken to support safe and pleasant walking spaces and cycle lanes, and to ensure land development has been oriented around transport.

The outcome of these policies has been to increase the share of journeys in Vienna city centre by public transport, cycling or walking from 68% in 2009 to 73% in 2015.³²

Lyon

Reliance on cars increased consistently from the 1960s until the 1990s, at which point political leaders were faced with the choice of building more expensive road tunnels to cope with continued growth in car travel, or changing direction. Since then the city has focussed investment on the metro network, trams, buses and a cycle route network. It was able to do so because it had the ability to develop, fund and implement a ten year Urban Mobility Master Plan covering €788 million of investment.

The result is that the share of journeys in the Lyon city region by public transport, cycling or walking increased from 49% in 2009 to 56% in 2015.³³

Bilbao

Like many UK cities, the economy of Bilbao suffered from industrial decline from the 1970s. This period coincided with decline in use of its public transport network until the 1990s, at which point congestion and a desire to regenerate the city as a knowledge services centre led authorities to seek to reverse this. Financial and political autonomy of the Basque regional Government helped it to plan for a series of new metro lines as well as modernising rail and bus connections linking to the new network.

Now 68% of journeys in the city region are by public transport, cycling or walking, with this figure rising to an impressive 89% in the city centre – among the highest in Europe and demonstrating what can be achieved with political commitment.³⁴

Car-focused public spaces don't support quality of life

There has been a lack of attention paid to making cities safe and pleasant places to live and work. Streets that are too exposed to cars are not pleasant places to walk, or to sit and relax. Noise, dust and fumes, as well as danger to pedestrians, create environments that are difficult for people to spend enjoyable time in.³⁵ The UK needs to ensure that it supports the growth of its cities in a way that enhances the quality of life of people living and working within them. Green infrastructure, such as sustainable drainage systems, can provide a more pleasant environment as well as delivering infrastructure services. Making it easier for people to walk or cycle offers opportunities to improve people's health by increasing physical activity.

'Air quality and climate change should be seen as the twin drivers of transport investment in urban areas.'

WWF call for evidence response

Air pollution remains the largest environmental risk to public health in the UK, and the Mayor of London has rightly made its reduction one of his key priorities.³⁶ Poor air quality also affects quality of life, productivity and the natural environment.³⁷ In 37 zones in the UK, annual limits for nitrogen dioxide pollution are exceeded.³⁸ The vast majority of these polluted zones are in cities, and nearly 80% of the nitrogen dioxide pollution responsible for breached legal limits is caused by emissions from road transport, especially cars and vans.³⁹ Particulate matter (microscopic particles in the air that can enter the lungs) is also a source of air pollution: diesel engines, braking and wear on tyres and roads all contribute to particulate pollution.

Empowering mayors and local leaders

London has benefited enormously from clear mayoral leadership since the establishment of the Mayor and Greater London Authority in 2000. Ken Livingstone, Boris Johnson and Sadiq Khan have enjoyed a mandate from Londoners to plan the strategic growth of the capital and transform its transport infrastructure. This has resulted in substantial public transport capacity increases, including upgrading of the Underground, Crossrail, cycle superhighways and the London Congestion Charge.

Nonetheless, London's infrastructure still faces long-term challenges, driven particularly by continuing population growth. The Commission has previously recommended in its *Transport for a World City* report that planning for Crossrail 2 should be progressed to relieve pressure on crowded stations, increase capacity through the city centre, and unlock new land for housing.⁴⁰ Any plans must include clear proposals to reduce and phase costs, and for London to provide more than half the scheme's funding.

Outside London, responsibility for city infrastructure tends to be fragmented and poorly organised. Transport operations are split between local authorities, national agencies and private rail and bus companies. Transport and planning for housing development are the responsibility of separate authorities. Plans for different forms of transport and for housing do not always work well together. Split functions makes it hard for cities to take forward service improvements such as a single transport ticket for different transport options.

There is also no major long-term funding programme for city transport in most of the country. City leaders have to bid to a wide range of funding sources, which come with limited long-term certainty and are not large enough to plan for major network-wide upgrades. By contrast national rail and road networks, and Transport for London, benefit from multi-billion pound investment programmes planned for many years in advance.

The Government has started to address some of this, committing that mayors will have multi-year funding settlements agreed as part of future spending reviews.⁴¹ 'Driving growth across the whole country' is a pillar of the Government's Industrial Strategy green paper.⁴² However, much will depend on how these reforms are implemented, including how well they are funded and what additional powers may be passed down to elected mayors over time (including in London), if they are to be empowered to develop strategies that integrate transport, housing, wider infrastructure and public services.

'The funding streams available for tackling congestion and investing in infrastructure are too complex and involve too much bureaucracy. Currently most funding is provided on a competitive basis by a number of different funders in a variety of different funding regimes, causing duplication and waste.'

Local Government Association call for evidence response

Land value capture

The majority of funding for transport infrastructure comes from Government. With constrained public finances, transport investments cannot always be funded even where there is a clear benefits case.

Improved infrastructure often increases the value of surrounding land and properties. These uplifts in land and property value can provide windfall benefits to those who own them. By funding projects based on their local capacity to capture this value uplift, there is a strong incentive for scheme promoters and designers to maximise the benefits of any scheme. Local funding can also strengthen local accountability.

Where the land value increase is significant, in areas of high property value, such as London, parts of the South East and some major city centres, this may be an important potential source of funding.

But in other parts of the country where property values are not as high, any contribution to the costs of new infrastructure from land value capture will be lower, and so these mechanisms are likely to play a less significant part in funding any new investment. Land value capture also depends on the state of the property market, which is uncertain and can be volatile.

For new developments, there are two existing mechanisms for development contributions. Section 106 of the Town and Country Planning Act 1990 provides a mechanism to mitigate site-specific issues, as part of obtaining development consent, such as infrastructure provision (e.g. access roads, utility connections) as well as the provision of social housing. The Community Infrastructure Levy is a charge based on new floorspace, set at local level where local authorities have chosen to introduce it. Charges may vary by location, use, size and type of development.

Stakeholders have highlighted a number of shortcomings with this system. Cashflow issues can arise when the costs of infrastructure need to be incurred before revenues are received. Developers perceive Section 106 agreements to be lacking in transparency. Local authorities perceive them as time-consuming and feasible often only for larger sites. Negotiations are costly for all involved, but constrained budgets, asymmetric information and bargaining power mean local authorities often find themselves out-resourced.

A recent review of the Community Infrastructure Levy suggests that it has failed to deliver the funds anticipated and, in many cases, to meet the demands of simplicity and efficiency it set out to achieve.⁴³ The Government is currently considering a reform of the development contributions system following the 2017 Housing White Paper.

Inter-urban transport

Road and rail connectivity within the UK is good: you can get anywhere by road, normally by a fairly direct route, and to most major population centres by rail. However, capacity is an increasing issue. Economic growth and an increasing population will increase demand and put extra pressure on networks.

Congestion on the long distance road network is primarily the result of combinations of local and long distance traffic. The long distance road network is designed to bypass city centres. However, orbital motorways like the M60 and M25 and arterial routes near major cities, such as the M42, M5 and M6 around the West Midlands, inevitably combine local traffic with longer journeys. The UK is simply too small for the long distance network to pass far enough away from major cities to avoid these overlaps.

'It is notoriously difficult for the planning system to capture land value uplift with existing mechanisms such as section 106 agreements and the Community Infrastructure Levy. This may be fine for site specific infrastructure spending such as a new highway junction but has limitations where significant new investment is required or as an approach to convince local residents that the existing infrastructure issues will be resolved.'

Greater Manchester Authority call for evidence response

'There is a significant level of short distance motorway travel (often referred to as junction hopping) [on the Strategic Road Network in the West Midlands]'

Transport for the West Midlands, response to National Infrastructure Assessment call for evidence response

It is possible, though expensive, to build more capacity on longer distance roads on the outskirts of cities, unlike in the city centre. But any such new capacity is still unlikely to solve the congestion challenge. Instead, it enables people to make different choices about where to live and work, and when and how to travel, which generate benefits for those individuals, but quickly fill up the new road space. Post-opening evaluations of major road schemes suggest that journey time savings, especially at peak times, tend to be lower than forecast.⁴⁴ Particularly in urban areas, increases in capacity lead to changes in behaviour with congestion generally returning to a similar level experienced prior to scheme opening.⁴⁵

After a long period of under-investment, the Government has committed to publishing and funding long-term road investment strategies every five years, which offers a mechanism for delivering much needed improvements.⁴⁶ Chapter 5 considers the longer-term challenges and opportunities for road infrastructure from changes in the nature of cars, as well as options for tackling congestion.

There are different challenges for intercity rail networks. There is a pipeline of upgrades which will provide enough capacity for long distance journeys for decades to come. HS2 will directly connect and significantly reduce travel times between eight of the ten biggest cities in the UK as well as airports at Manchester and Birmingham. East West Rail would improve connectivity along the corridor linking Oxford and Cambridge.

The Commission has already recommended additional investment in connectivity between major Northern Cities in its **High Speed North report**. This should include taking forward an enhanced 'HS3' rail network, beginning between Manchester and Leeds, the two largest economies in the North, and an early boost in road capacity on the M62. Further work is needed to develop and agree a prioritised strategy for HS3, but the aim should be for the initial phases to be delivered broadly alongside Crossrail 2 in London. Transport for the North is leading work in this area, and is committed to preparing an integrated plan linking proposals for HS2 and HS3 by the end of 2017.

The completion of HS3 and Crossrail 2, and their integration with the HS2 network, will transform the reach and capacity of the transport systems serving our major cities. Undertaking them in parallel will help to balance the national pattern of infrastructure investment, supporting sustainable economic growth across the UK's regions.

While the Government has shown ambition in the programme of inter-city rail investments, it has not always been successful at delivering them. Network Rail was unable to deliver in full its rail investment programme for 2014-19 as costs escalated. Many communities were disappointed as significant projects were rescheduled.⁴⁷ More recently the Government has announced the cancellation of rail electrification projects in the North, Midlands and Wales.⁴⁸ It is important that the Government's new plans, using bi-mode diesel electric trains, deliver the same benefits for capacity and journey times that were promised as part of the original electrification proposals.

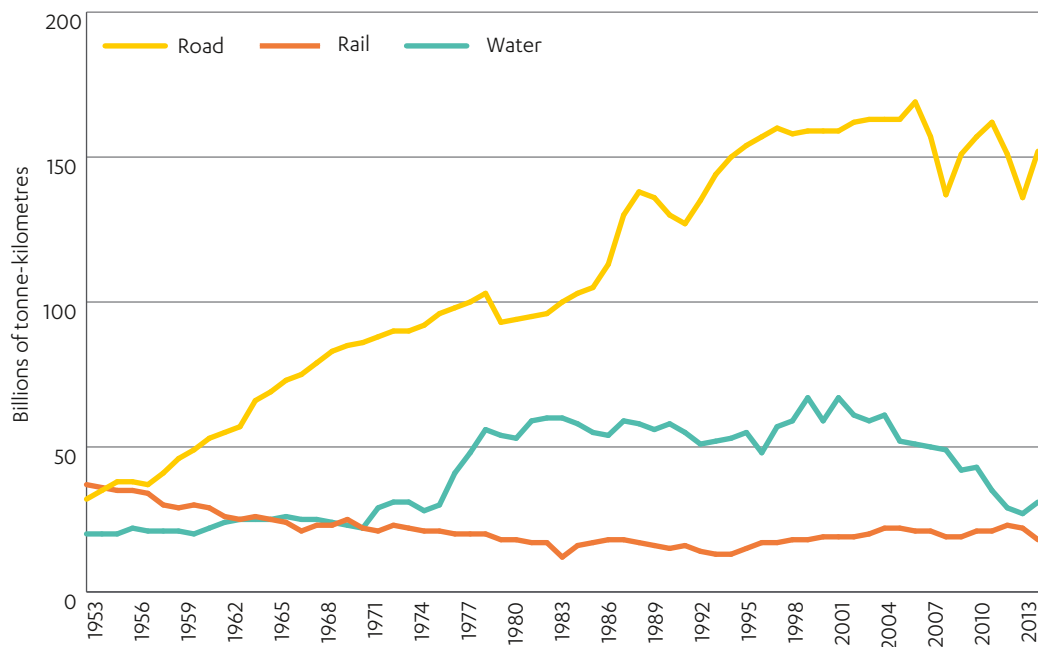
The high costs of committed investment on the main inter-city routes, as well as of simply maintaining the existing network, limit the scope for expanding rail into new markets. The development of safer, quicker, non-polluting cars also creates significant uncertainty about the role of rail in some markets. However, road transport is unlikely to supplant rail in its core markets: commuting into city centres (where physical road space is a key limitation) and long distance city centre-to-city centre travel (where rail has a speed advantage). The priority should be to maximise the benefits of rail in its core markets, where it is cost-effective, and to integrate it effectively with technological developments on the road to deliver more intermodal travel options.

Long-distance freight

Businesses need to be able to move goods between ports, airports, production and distribution sites, and to their customers as efficiently as possible. Poor connectivity and congestion impact on costs, which are ultimately passed through to prices affecting UK consumers and international competitiveness.

The majority of freight is transported by road. Over longer distances and for certain types of goods, rail becomes more competitive. Total volumes of rail freight have remained broadly constant over the last 50 years, while volumes on the road have doubled (see Figure 2.6).

Figure 2.6: Domestic freight transport 1953 - 2015⁴⁹



An argument for shifting freight from road to rail is often made on grounds of congestion and environmental benefits. Rail freight will always have its place, and some enhancements may be cost-effective, but the Commission believes the pilots of “platooning” truck convoys on motorways and major A roads may open the way to radical improvements in the efficiency and capacity of major freight distribution by road in the future (see Chapter 5). This would free up rail capacity for enhanced commuter and inter-city passenger services. The Commission will report further on this in the future.

Rail freight is already increasingly limited by network capacity as passenger demand increases. The issues with mixed traffic on the network are well documented – freight trains travelling at 70mph on the same track as passenger trains travelling at 125mph results in a significant capacity constraint.⁵⁰ Whilst freight can travel at night in some areas, this competes with maintenance work, which also needs access to the track at night.

Reducing road freight by only one-third would require more than a three-fold increase in rail freight capacity, which simply could not be accommodated on today’s already busy railway.⁵¹ The Commission believes that upgrades needed for this sort of shift would be prohibitively expensive, whilst the benefits would be questionable, particularly if truck platooning is successful, given the industry’s clear preference for road transport in most cases.

Ports and airports

Ports and airports support international competitiveness and quality of life by enabling people to travel for business and leisure and supporting the export of British-made goods and services. Most ports and airports in the UK are in the private sector.

Air travel continues to grow. Social research undertaken on behalf of the Commission shows the continuing desirability of international travel.⁵² Analysis by the independent Airports Commission concluded that a new runway at Heathrow airport was needed and would provide sufficient capacity for the UK until 2040 at least.⁵³ Increasing UK aviation capacity also requires modernisation of the air traffic control system, on which the Government has recently consulted.

Good surface access to airports enables more efficient travel for UK passengers and contributes to the attractiveness of the UK to international travellers. Road is the dominant surface access mode.⁵⁴ The value for money case for increasing the public transport mode share is often challenging. In many cases the provision of new rail links is unlikely to be cost-effective unless wider benefits can be realised – the incorporation of Gatwick Airport as part of the Thameslink programme provides an example. Apart from at Stansted and Gatwick, people tend to access major airports by car, even where there is good connectivity: for example, only 23% of passengers use rail to access Birmingham International airport, even though it is on the West Coast Main Line.⁵⁵

Activity at UK ports is influenced by global economic trends and market forces in shipping. Ports handled over 95% of goods by volume passing through UK international gateways in 2015, with airports predominantly carrying high value and time critical goods.⁵⁶ The changes in UK energy policy have had a major impact on freight flows at ports handling coal.⁵⁷ Growth in container freight has concentrated activities at the country's southern ports although Liverpool has recently invested in additional container capacity. Ports are expected to have, or be able to develop, sufficient capacity in aggregate for the foreseeable future.⁵⁸ The shift to using larger 'New Panamax' vessels will create challenges in some port locations in finding space for larger berths.

Ensuring efficient security and custom clearance processes is an important part of the accessibility for both passengers and goods. The importance of road and rail access to allow freight to be moved easily through ports needs to be recognised in the Government's strategic investment plans.

Reducing greenhouse gas emissions from aviation and shipping will be a significant challenge, but one that the UK alone cannot address. A number of options exist to reduce emissions, but it is not clear at present whether they could be reduced to the same degree as land transport.⁵⁹ The Commission may need to return to this issue in subsequent Assessments, when there is greater clarity on the potential options. In part, the need to completely remove greenhouse gas emissions from electricity generation, heating and land transport to achieve the UK's target of 80% overall reductions reflects the difficulties of significantly reducing emissions from aviation and shipping.

The Commission's priorities

The UK needs to enable its cities to grow, supporting economic growth and a high quality of life. This will require better urban infrastructure, a more strategic approach and dedicated funding.

Technology

Technology provides many opportunities to enhance the effective capacity of urban transport networks, without the need for new physical capacity. Chapter 5 considers the potential of new technologies that are transforming cars.

The effective capacity of road networks could be enhanced by greater use of network control centres. Transport for London operate a control centre, managing traffic signalling to send vehicles away from the busiest areas and respond quickly to incidents on the network. The Commission's technology study is examining the scope for future traffic signalling technology to increase the flow of people on existing roads.

Smart motorways allow more people to travel on the busiest parts of the network at peak times, whilst maintaining safety, by using technology to actively manage the flow of traffic. The capacity of the road is increased, without the expense and hassle of widening the road, by either temporarily or permanently opening the

hard shoulder to traffic.⁶⁰ Traffic control measures can regulate access to the main carriageway, reducing congestion and improving traffic flow.

Wider dissemination of more accurate 'real time' information on delays and travel times, incidents, alternative routes and mode options would also contribute to managing congestion. Information on the real cost of journeys could also encourage efficient decision making.

On railways, digital signalling and train control can increase capacity on some of the most congested lines, by improving the efficiency and reliability of train operations.⁶¹ Strategic Outline Business Cases have been developed for some of the busiest routes and development work should be progressed where the case looks strong.

New technologies could also drive down the cost of disruptive road and rail maintenance and renewals. Sensors, combined with artificial intelligence, can help identify where problems are going to occur and enable more efficient and better planned maintenance.

Funding

Transport between cities, on the national road and rail networks, is now well funded with multi-billion pound, long-term spending programmes set out by the Government. As these programmes are developed, it will be important to balance the needs of both passengers and freight, in particular connectivity to international gateways.

Transport within cities – particularly outside London – does not have either the same certainty or level of funding. It is important that a new approach to funding is developed which will enable other city regions to develop and implement long-term strategies for the enhancement of their intra-city transport networks. This should include flexibility to use funding not only to build new infrastructure, but also to improve services where this offers a more cost-effective way of increasing capacity. And it should provide enough certainty over future funding levels to provide confidence that the plans that are developed can actually be delivered. Funding for city transport will also need to be adequate to enable authorities to proactively maintain the networks that already exist.

'The availability of capital funding for combined authorities to tackle transport problems fluctuates and there is a strong case for capital spending to be agreed over a long term (10-20 year) period.'

Black Country LEP call for evidence response

Over the 2020s, planned expenditure on HS2, HS3 and Crossrail 2, together with ongoing investment in the strategic road and rail networks, means that additional funding for urban transport is likely to be constrained. This should not, though, stop Government from supporting cheaper and quicker options, such as better bus services and new tram-style bus rapid transit networks.

Once expenditure on these major national investments begins to tail off, and once cities have already adopted cheaper and quicker to implement options, there is likely to be a case for prioritising more significant levels of funding of intra-urban infrastructure.

Given the timescales needed for infrastructure planning and delivery, it will be important for Government to provide early commitment to such a transition. This will provide city leaders with the time and clarity they need to prepare effective long-term strategies, which could include more intensive investment such as trams or increased urban rail capacity. There may be also opportunities to use private finance (discussed in chapter 7) to help bridge any timing gap.

Setting the right framework now will help cities plan for the future. Combined with effective devolution of powers to enable integrated infrastructure planning, this could support transformational change in major cities across all the regions of the country.

It is important funding programmes for cities focus on how investment in transport can help improve housing and economic performance and not simply on how it reduces congestion.

Areas of very high employment density require more intensive transport investment to sustain them. They also generate a lot of economic activity, providing the revenues needed to pay for that investment. That said, transport investment in London and its surrounding regions has been consistently higher relative to the size of its economy (1.25% in 2015) than in the North (1.15%) or the Midlands (0.96%).⁶²

The Commission's work on performance metrics will help to indicate where investment could have the greatest impact on the economic growth and vitality. It is important to address the needs of cities outside of London in the context of their credible potential for growth.

The Commission will also explore reforming and developing new mechanisms to capture land value. Land value capture is not a panacea to pay for all infrastructure needs. But it may be able to play a role in ensuring a fairer distribution of the costs of infrastructure between general tax payers and property owners who receive windfall gains. It could also help ensure that the infrastructure needs of London and the South East – where land value uplift can make a more significant contribution to costs – are less directly in competition for national funding with the needs of other parts of the country.

Making it happen

City leaders need to take strategic control of urban planning and public transport systems. As part of this devolution, city-level transport authorities should be given powers over the local road network to ensure that public transport has the priority it needs to provide a rapid and popular service. This should include the option to levy congestion pricing.

Leaders need to be able to plan for infrastructure and housing together. This is already what happens for major development in London as well as in some cities with unitary local authorities that combine transport and development

'Devolution of powers would mean that a long term programme of activity can be planned, rather than dealing with schemes on an ad hoc basis, therefore enabling projects with transformational impacts to be properly planned, appraised and delivered.'

North East Combined Authority call for evidence response

planning powers in one place. Improving the economic analysis of transport proposals would help promote integrated housing and transport planning, by ensuring that planners and decision-makers had better analysis of the true sources of value generated by urban transport investment. The Commission will explore what improvements can be made and how.

As well as housing, city leaders may be well placed to make the most of the opportunities that infrastructure creates for new business development. For instance, Greater Manchester have put forward an innovative proposal to take over management of rail stations in their area, with a view to integrating station design with redevelopment of the space around them. The case for piloting this approach in medium-sized stations is very convincing, and it may even be possible to extend this to include pivotal city centre stations, particularly given their wider potential role as integrated transport hubs.

Alongside this, the Commission intends to work more directly with a number of key city regions to support them in developing long-term infrastructure strategies which reflect their individual patterns of economic development and population and employment growth. Whilst transport planning will be central to this work, given its key role as a driver of growth and liveability, it should not be its sole focus, and the Commission will encourage consideration of the full range of potential infrastructure priorities within each city region.

Given the opportunities opened up by their new powers and increased autonomy, the Commission is engaging closely with the recently elected metro mayors. This work will inform the National Infrastructure Assessment.

This process will be iterative and the Commission also plans to use this initial period of engagement, carried out in parallel with the Assessment, to develop a ‘toolkit’ for city leaders. This will provide them with a framework for strategic infrastructure planning, enabling them to better realise the potential offered by any increased funding in the medium to long term.

‘We need to ensure the coordination of transport and land use planning so that denser urban development can be served by mass transit systems. Densification enables more efficient, interconnected mobility solutions which could alleviate congestion and improve air quality.’

Merseytravel call for evidence response

The Commission’s vision

Meeting the Commission’s 2050 vision would see the UK have:

- Thriving cities in every region, where people want to live and work. Dense concentrations of employment, driving up productivity and creating opportunities for firms and workers.
- Integrated, properly funded, city-region strategies for infrastructure – with a focus particularly on transport and housing. Better public transport alongside pricing for roads, resulting in reduced congestion in central areas. Road space which has been reallocated for fast, frequent bus and tram services and more car-free areas for leisure, shopping and socialising. Urban freight fully integrated into transport strategies.

- Frequent commuter rail services with more seats, enabling the growth of housing around cities. Connected, autonomous cars providing a valuable link from suburban homes to high density transport hubs, but not replacing public transport in city centres, where lack of space will remain the main constraint.
- A well designed urban realm, making cities green and liveable and reducing pressures on infrastructure networks. Places which support a wide range of cultural, leisure and social activities, enhancing quality of life. Electric vehicles giving cities their cleanest air since the industrial revolution.
- Fast and efficient road and rail connections between cities, as well as international gateways which support both holiday travel and trade in goods and services.

Questions for consultation

The economic benefits of concentrating economic activity in cities is driving the growth of cities, but this is causing congestion on city transport networks and a shortage of land for housing. Congestion can't be solved by simply building more roads, and current arrangements for infrastructure planning aren't joined up with planning for new housing.

- 9) **What strategic plans for transport, housing and the urban environment are needed? How can they be developed to reflect the specific needs of different city regions?**

Currently there is no stable long-term funding arrangement for the major investment needed in city transport outside London. Making this a priority would mean trading off against other objectives within limited resources for transport investment, which is especially difficult in the 2020s given existing commitments for major road and rail links between cities.

- 10) **What sort of funding arrangements are needed for city transport and how far should they be focused on the areas with the greatest pressures from growth?**

Capturing a greater portion of land and property value uplift could help to fund infrastructure. However, the potential for uplift differs dramatically across the country.

- 11) **How can the Section 106 and Community Infrastructure Levy regimes be improved to capture land and property value uplift efficiently and help fund infrastructure? Under what conditions are new mechanisms needed?**

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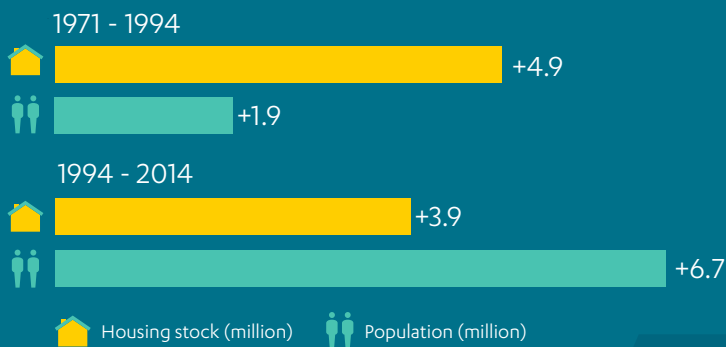
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3. INFRASTRUCTURE TO SUPPORT HOUSING



WE NEED MORE HOMES:

Between 1971 and 1994 housing stock in the UK rose by 4.9million, while population in the UK rose by 1.9million; conversely, between 1994 and 2014, housing stock rose by 3.9million, while the population rose by 6.7million



Since 1955 the price of housing has risen five-fold and land values 15-fold – making it difficult for people to find suitable and affordable homes near to where they work



BUT WE DON'T MAKE THE MOST OF OUR INFRASTRUCTURE:

Without better coordination, new homes won't take advantage of existing infrastructure



1

The value of homes located near infrastructure is reflected in property prices. Those within 500m of rail and tube stations in London have a 'transport premium' of the price up to

+10.5%

2



Planning and delivery of utilities for major development can take months, and sometimes years

3



Infrastructure and housing must be planned in tandem from the outset

A Better Future

INFRASTRUCTURE SUPPORTING HOMES AND COMMUNITIES

Infrastructure must help deliver new homes and create vibrant communities

1

Better coordination

in the design and delivery of homes and infrastructure – using strategic maps



2

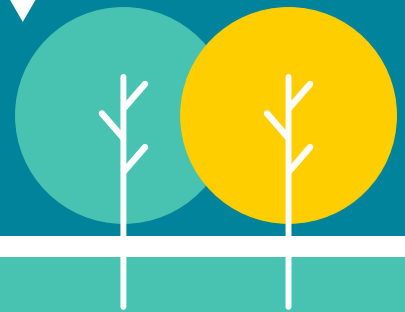
Better incentives for utilities providers

to deliver in time for new housing – and public funding that recognises the value of housing growth

3

Well-designed infrastructure and public spaces

connected to housing, improving quality of life



The need for action

One of the UK's major infrastructure challenges is housing its growing population. The issue is felt most acutely in areas of strong demand where population density is already high. There is a clear interaction between infrastructure and housing. Infrastructure needs to promote new housing and new communities in areas where they are needed.

Between 1971 and 1994, the housing stock in the UK rose by 4.9 million (over 25%) while in the same period the UK population rose by 1.9 million (3.5%). However, from 1994 to 2014 the UK housing stock increased by just 3.9 million (around 16%) whereas population is estimated to have risen by 6.7 million (11.6%).^{1,2} After a long period of falling household size, there was little change in this indicator from 1991 to 2011 in England and Wales.³

A more constrained supply has contributed to a long-term worsening of affordability, especially in high demand areas. Since 1955 the price of housing has risen fivefold in real terms, leading to land prices rising fifteen-fold.⁴ However, constrained supply is by no means the only factor behind the increase in real house prices, and the problems in the housing market will not be resolved simply by building more units.

Infrastructure should support housing growth rather than being another barrier. Infrastructure alone will not solve the UK's housing challenges, but better coordination of infrastructure with new developments is vital if infrastructure is to be deployed effectively.

At the most functional level, new developments are dependent upon the provision of utilities (electricity, gas, water and digital communications) and transport. But the interrelationship between infrastructure and housing reaches beyond the practicality of a development. If properly deployed, infrastructure can support developments turning into liveable communities – informing more suitable housing locations and being integral to the design of desirable places to live and work. This potential is hindered by shortcomings in the current system.

A coordinated approach to infrastructure and new development can also help make new development acceptable to existing communities. Over-stretched infrastructure fuels resistance to new housing, so infrastructure enhancements can help councils embrace growth and grant planning permission with fewer local objections. This has been a key factor in the Commission's work on the Oxford-Milton Keynes-Cambridge growth corridor: proposed alongside significant and much-needed transport infrastructure, there can be a far greater willingness on the part of the local residents and their political leaders to embrace a bold approach to homebuilding. After all, it is the children of existing residents who are often the ones finding it hardest to get on the housing ladder because of the failure to build more.

How things stand

Currently, the provision of the infrastructure necessary to unlock new housing is too often not funded, timed or delivered in a way that facilitates or expedites housing delivery. Where infrastructure assets are already in place, local plans should strive to ensure that new housing can make use of them. Despite some positive examples, more could be done to coordinate infrastructure and housing on a systematic basis.

Currently, local authorities issue a 'call for sites' to identify the land developable for housing. The assessment of land availability is an important step in the preparation of Local Plans.⁵ In filtering suggested sites, authorities will evaluate them against a range of factors including connectivity to infrastructure. In this way, infrastructure forms part of the evidence base that an authority will present to the planning inspector to demonstrate the 'deliverability' of a site at a plan's Examination in Public.⁶ However, this falls short of a coordinated strategy to ensure that infrastructure assets are used to their full capacity to support housing development, or that housing is planned in a way that maximises the returns from new infrastructure investment.

Responses to the Commission's Call for Evidence urged better integration. The Royal Academy of Engineering felt that infrastructure, housing and work places should be planned as a single, integrated system; while the Royal Town Planning Institute recognised that some infrastructure could be guided by housing, but housing should be directed by transport infrastructure.

Densification around urban infrastructure hubs, notably bus or railway interchanges or near city centres, could help to provide much needed homes in high demand and desirable locations. The Greater London Authority already uses public transport accessibility (as part of its sustainable residential quality matrix) as a guide to where high density housing could be delivered, and the Commission suggests that this approach should be adopted more widely.⁷

For many people, existing and potential employment is the main driver for where they choose to live. Housing pressure points have arisen around economically successful centres. Alleviating that pressure is not easily achieved by increasing supply elsewhere – the UK is a network of very local housing markets, weakly connected in economic terms.

Densification in high demand areas could help meet housing need and enable people to live closer to where they would like to work. It also releases pressure on the transport network if it can enable more people to walk or cycle to work. In exceptional cases, this co-location could warrant some degree of development around existing infrastructure hubs in the green belt, where that allows for new housing in an optimal infrastructure location and is not inconsistent with the planning purposes of the green belt. This could ultimately reduce the overall environmental impact and footprint of development – for instance by avoiding the need for new settlements or infrastructure to be built on the other side of the green belt.

Making infrastructure work for housing – Greater Manchester and Kent

The Mapping GM project has created open data infrastructure maps to help the Greater Manchester Combined Authority coordinate housing, planning and infrastructure.⁸

- The Greater Manchester Open Data Infrastructure Map (see Figure 3.1) provides developers and planners with infrastructure and housing related information across Greater Manchester on a single, easily accessible map. Drawing data from the public and the private sector to provide a general overview of physical, social and green infrastructure, the map also captures data on heritage, flooding, property prices and river quality.
- The ‘Call for Sites’ map was developed to support the process of asking local residents, businesses, land owners and developers to identify sites they thought could be suitable for housing or employment development, feeding into the Greater Manchester Spatial Framework.
- The Greater Manchester Spatial Framework consultation map was designed to support consultation on the spatial framework, a joint plan within which Greater Manchester’s ten local planning authorities can identify more detailed sites for jobs and homes in their own area.

The spatial framework seeks to:

“ensure that we have the right land and in the right places to deliver the homes and jobs we need up to 2035, along with identifying the new infrastructure (such as roads, rail, Metrolink and utility networks) required to achieve this”.

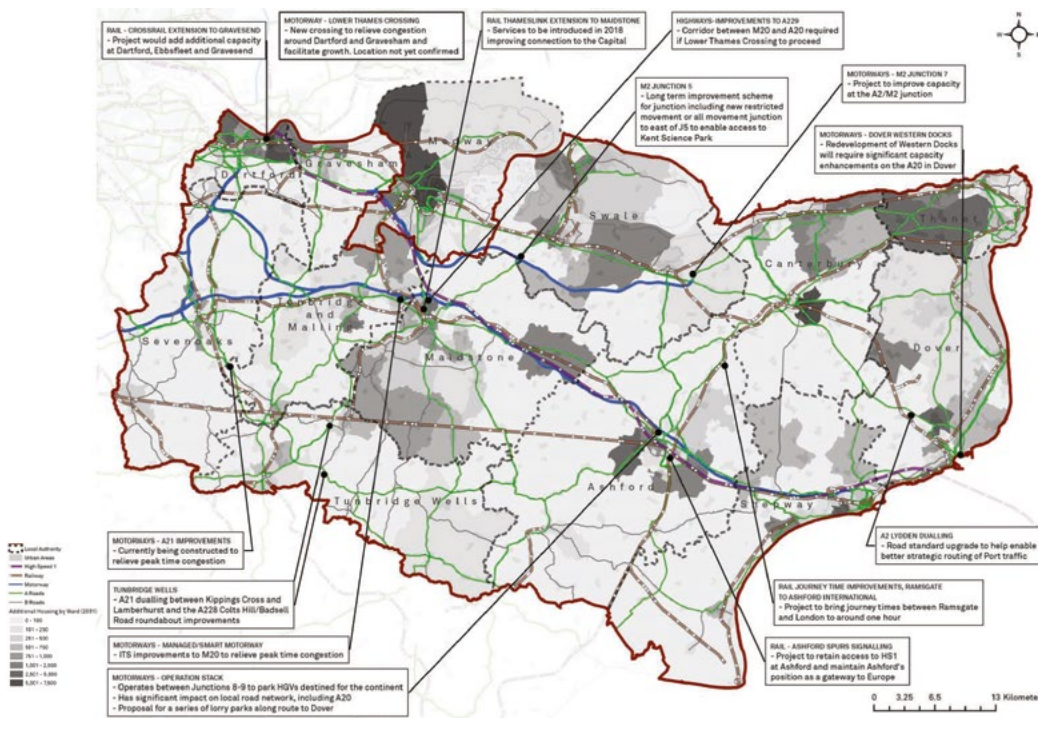
Kent County Council is using county-wide infrastructure mapping as its starting point to ensure that new developments are delivered as part of desirable communities. The Council costed the infrastructure needs across the county to produce a ‘Kent and Medway Growth and Infrastructure Framework’.⁹

The Kent framework calculated impacts on economic and social infrastructure, in order to examine barriers to residential and commercial property growth. It identified ‘secured funding’, ‘forecast funding’ and funding gaps in order to ascertain what infrastructure would be required to deliver housing and commercial property growth to 2031. The work has enabled Kent to map their infrastructure hubs across the county, providing the capacity to inform planning at the local level. Examples of this are shown in Figure 3.2.¹⁰ It has led to constituent district councils looking at where transport and utilities are located in order to plan for housing.

Figure 3.1: Greater Manchester mapped data



Figure 3.2: Kent and Medway proposed cross district transport projects



Coordination

Work towards a more coherent approach to infrastructure and housing is taking place in some places, such as Greater Manchester and Kent (see box). But too often coordination is insufficient.

Coordination requires the alignment of diverse sectors, delivery agencies, local authorities, regulatory frameworks and interests. This diversity has created a disjointed landscape that is neither efficient, nor conducive to facilitating new developments. It is not realistic for infrastructure providers to respond to 338 local

plans.¹¹ Some form of more strategic engagement could substantially lower the costs of coordination between housing developments and infrastructure.

The Localism Act 2011 replaced formal structures for cross-boundary, strategic planning with bottom-up approaches to making the best use of space and assets across local authority boundaries, including the option of joint plan-making.¹² The 'duty to cooperate' introduced by the Localism Act recognises the need for authorities to work across boundaries to identify land for their five-year housing supply. This could allow a strategic perspective to be adopted, identifying infrastructure capacity, hubs and gaps in order to guide housing delivery, as in the Kent and Manchester models.

The emergence of combined authorities and city-region with mayors is providing greater strategic vision and planning in some parts of the country. The Commission strongly encourages other cities and sub-regions to adopt these models in order to empower the planning and delivery of essential infrastructure. The growth potential in areas with effective strategic infrastructure plans should encourage investor confidence and engagement from property developers and infrastructure providers. The Commission also notes the power of the Government to direct 'joint plans' and believes this power should be used strategically.¹³

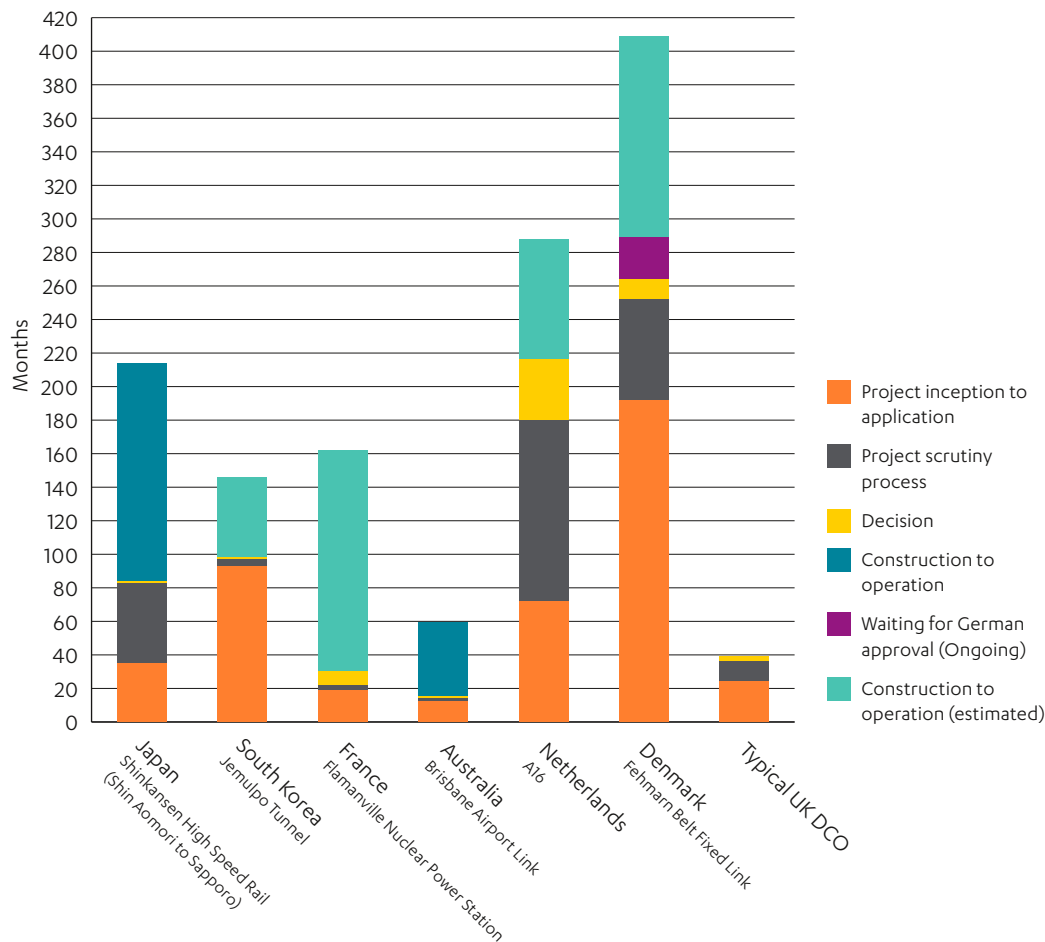
Planning consent and nationally significant infrastructure

Several consenting procedures are used in the UK for significant infrastructure projects, including the 2008 Planning Act and hybrid bills. Responses to the Call for Evidence including from Thames Tideway Tunnel and the National Infrastructure Planning Association (NIPA) suggest the 2008 Planning Act has generally been a success, with developers stating it provides some predictability for planning nationally significant infrastructure. National Policy Statements are helpful in setting out the UK Government position and objectives in relevant sectors but recent research makes a number of recommendations for achieving a better balance between detail and flexibility in the Development Consent Order process.¹⁴ Hybrid bills can provide another consenting procedure for the most significant infrastructure, but can be less predictable given the need for Parliamentary time.

Whilst there have been high profile delays in the UK, many other countries also experience delays for large infrastructure projects. Overall, there are a range of outcomes, with many UK projects delivered with little delay and the Nationally Significant Infrastructure Projects regime reducing the number of separate applications and permits needed for many projects. Figure 3.3 shows the timescales for different stages of a small sample of international projects. Although it is difficult to make comprehensive comparisons, research for the Commission suggests that the UK performs similarly to comparable countries.¹⁵

Recent changes to the Planning Act regime allow housing linked to a qualifying infrastructure project (up to a maximum of 500 dwellings) to be included in applications for Development Consent Orders.

Figure 3.3: Comparison of international project timescales



Better incentives for delivery of infrastructure

Poor coordination flows not only from the way that development is planned, but also the incentives and funding for infrastructure providers to invest and deliver according to future need. The current regulatory framework for utilities is predominantly focused around protecting existing customers. Without regulatory support, infrastructure providers are often reluctant to take the risks involved in providing infrastructure ahead of new housing developments since they cannot recover their costs if the housing is delayed.¹⁶ However, this in turn can create delays in housing development because the infrastructure itself can take considerable time to install.

Electricity distribution offers a vivid case study of the difficulties caused by fragmented delivery and low market responsiveness. The Commission's analysis of utilities provision in the Cambridge-Milton Keynes-Oxford growth corridor, drawn from discussions with local authorities and infrastructure agencies in the region and responses to the Assessment's Call for Evidence, indicated that electricity was a major barrier to new development – a finding also recognised by Ofgem (the regulator).

Ofgem has published a study of electricity connection constraints, reporting that new customers were unable to connect in areas where the network could not distribute more electricity, affecting the level of investment required for reinforcements.¹⁷

The Ofgem study also found that customers were unable to connect to the network even where there was capacity, if customers earlier in the queue were holding onto capacity they did not need. This could result in higher costs for new customers and mean that developments were delayed, transferred to another part of the network or simply stalled.

Ofgem are challenging distributors to make the best use of existing capacity and to trial the case for building new capacity in advance of need. The Commission strongly encourages Ofgem to act strategically in this manner to encourage new housing and community infrastructure when it is clearly needed. But it is recognised that there is still more to be done.

Electricity is not the only challenge. Full fibre is often the most cost effective digital connectivity solution for new developments, which would allow new homes to have first class connectivity from the outset. A lack of cooperation at a sufficiently early stage of the planning process undermines the effective deployment of digital infrastructure. The regime for digital infrastructure differs to other utilities such as electricity and water, with no requirement on developers and telecoms providers to ensure proper provision to new housing developments. Retrospective civil works to deploy digital infrastructure for new developments is inefficient, costly and causes unnecessary disruption. The Commission encourages Ofcom to promote more integrated planning of mobile telecoms and fibre infrastructure alongside new house building and the planning of new settlements.

The Commission's priorities

An integrated approach to infrastructure and housing, using tools like digital mapping alongside good design, would allow for a more effective use of space, infrastructure assets and the environment.

Technology

Technology can support planning and investment coordination of infrastructure and housing. Mapping tools offer several ways to do things better:

- enabling developers to identify who owns the infrastructure so that they can ascertain the costs of connections or reinforcements.
- promoting efficiencies because providers can see how many developments might need supply and so plan to meet those needs in as a whole, rather than provide piecemeal reinforcements.

- highlighting smaller developments, which can cumulatively push utilities over capacity, but are not ordinarily on the radar of infrastructure providers because they do not require an environmental impact assessment. In turn, mapping offers more potential for developers to form consortia to finance utility reinforcements.
- informing housing location decisions, including where it would be most sensible to densify development, notably around transport hubs.
- creating dialogue between different infrastructure sectors in the process of creating a map, that can lead to more coordinated working.

Funding

Where the infrastructure needed to support new housing is within the public sector, it may have to compete for limited public sector funds. It is important therefore that processes to allocate funds, for example for roads, rail and flood risk management, recognise the value of housing growth. Chapter 2 looks at the importance of integrated strategies for housing and transport infrastructure and at the issue of land and property value capture as a potential source of funding for infrastructure projects.

As set out above, funding issues can also lead to delays in the provision of private sector infrastructure. Stakeholders have pointed particularly to challenges in electricity distribution, where Ofgem has made a number of proposals, but also to challenges with other networks. The Commission is interested in whether more can be done, beyond existing proposals, to ensure funding is available to support timely network upgrades.

Where funding for new infrastructure is available, cash flow issues can still be a major block to new housing. Infrastructure needs to be built before new developments can be completed, creating a need for upfront financing. Chapter 7 looks at the role of private financing in enabling infrastructure projects to go ahead.

The Commission's work in the Cambridge-Milton Keynes-Oxford growth corridor has also highlighted the key role of securing prior resources to drive strategic development. The growth of Milton Keynes has in the past benefitted from a development corporation which owned land and was able to masterplan and organise delivery with strong financial confidence. The certainty provided by access to finance combined with the planning and funding powers and delivery capacity that development corporations bring, were critical for Milton Keynes' expansion.¹⁸ The Commission will be considering the adaptation of the new town development corporation model to contemporary conditions, including the greater need for local democratic engagement.

Making it happen

Maximising the opportunities for infrastructure to support housing growth and vice versa will require a combination of:

- **Better coordination in planning processes:** bringing together different infrastructure delivery agencies, local planners and housing developers to develop mutual understanding and coordinated investment and delivery plans.
- **Intensifying density in city centre locations in high demand cities:** well-designed, denser development, including ‘above’ and ‘around’ station developments, could open housing around existing infrastructure, while also releasing pressure on transport systems by enabling more people to walk or cycle to work.
- **Enabling strategic spatial coordination:** Metro mayors and devolution deals offer the chance to capture the benefits of the city-region spatial planning level, which is necessary to design infrastructure intelligently and join different housing markets and economic areas.
- **Improving market responsiveness through regulatory frameworks and financial incentives:** allowing and incentivising infrastructure providers to invest in advance of demand, so that infrastructure responds well to the housing market. Targeted advanced investment, in areas where significant growth is certain, could help for instance. The Commission will be interested in comparisons and proposals between different regulators.

The Commission’s vision

The overarching vision is clear. The UK needs infrastructure that helps create desirable, thriving communities rather than a series of loosely-connected developments. New settlements, large urban extensions or opportunity areas within existing cities provide huge potential for creating state-of-the-art housing facilitated and reinforced by state-of-the-art social and economic infrastructure. Good design is crucial to this. Good design is about ‘problem solving’ as much as ‘beautiful aesthetics’. It needs to play a central part in planning new settlements, large and small. Hence the Commission’s proposal for a national design panel for infrastructure.

The UK’s housing challenges need speedy resolution, and this will be a key issue for the Commission in the 2018 National Infrastructure Assessment.

Consultation question:

Currently, infrastructure and housing are often not financed, designed, timed or delivered compatibly, which leads to infrastructure delaying housing delivery.

- 12) **What mechanisms are needed to deliver infrastructure on time to facilitate the provision of good quality new housing?**

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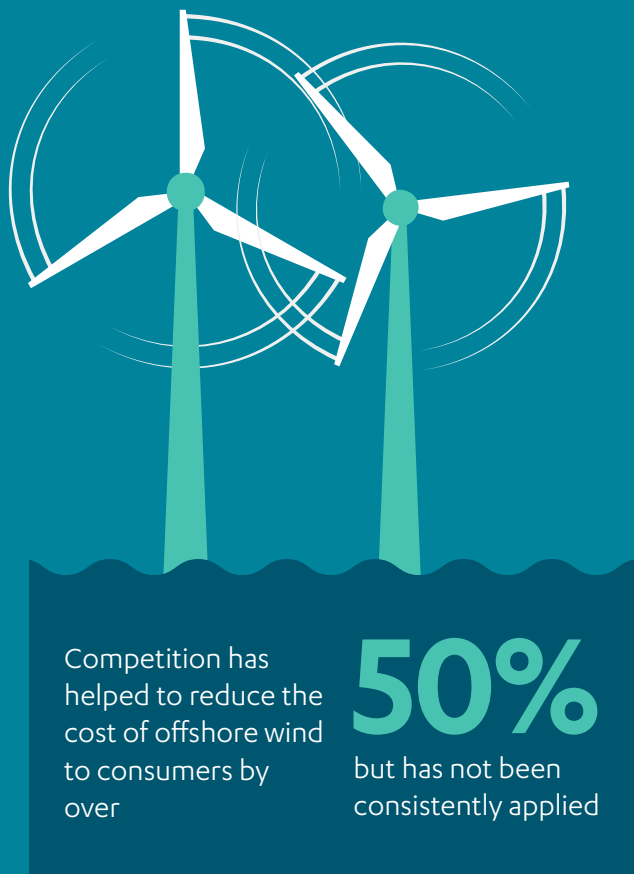
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4. ELIMINATING CARBON EMISSIONS FROM ENERGY AND WASTE



THE UK NEEDS LOW COST, LOW CARBON ENERGY AND WASTE INFRASTRUCTURE

Between 1990 and 2016 emissions from energy supply fell by 54%:
Emissions from waste management have fallen by 73%



MORE ACTION IS NEEDED

current plans would at best deliver

ONLY 50%

of the required reduction in emissions by 2030

This starts with reducing the amount of waste created, improving the UK's building stock and using competition to keep prices low

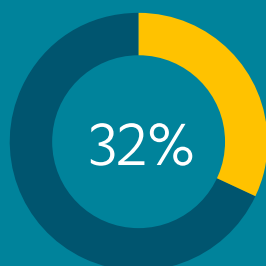


In 2015, households and business produced

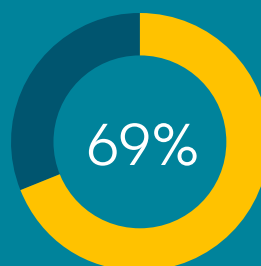


BUT THERE ARE BIG DECISIONS ONLY THE GOVERNMENT CAN TAKE

1 What is the best solution for providing low carbon heat?



of the UK's CO₂ emissions come from heating – this must be radically reduced



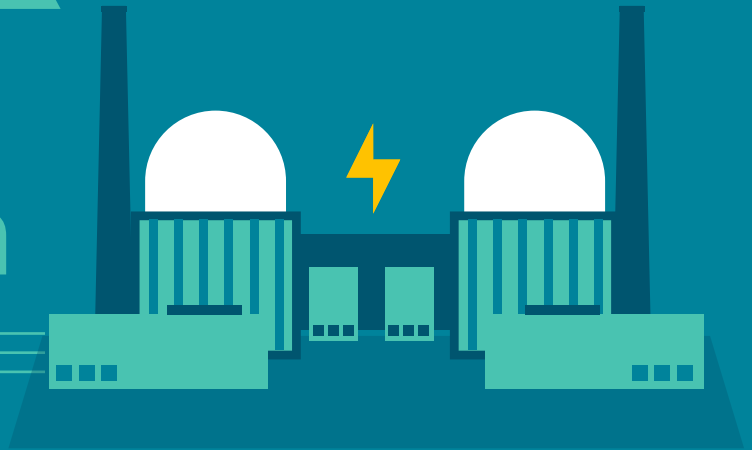
of heat production is from burning natural gas



2 How much new nuclear power may be required beyond Hinkley Point C?

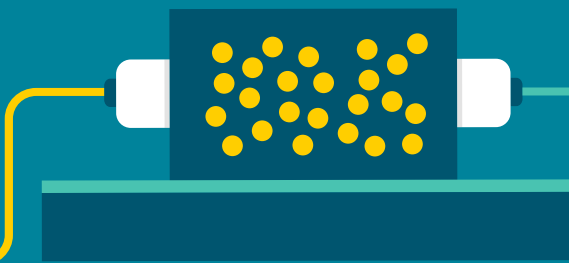
New nuclear power stations are expensive but could form a cost-effective part of the system in future: Hinkley Point C is projected to cost

£19.6billion



3 Does the UK need to invest in carbon capture and storage infrastructure?

Carbon capture and storage is a possible alternative way of reducing emissions from electricity, heat and industrial processes



A Better Future



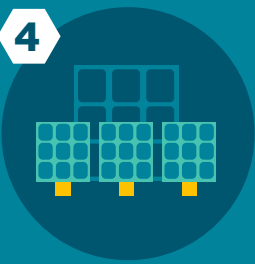
Abundant low cost, low carbon energy



Less waste and more efficient, sustainable treatment of the residual waste



Low carbon heat provision; with fossil-fuelled boilers a thing of the past and highly energy efficient buildings



Successful exploitation of the falling costs of low carbon technologies



A more flexible energy system, managed using a range of smart technologies to complement intermittent renewable generation

Sources: CCC, BEIS, CMA, Defra, EDF

The need for action

The UK's energy and waste infrastructure systems are undergoing fundamental change. As part of a global desire to limit the impacts of climate change, the UK introduced a legally binding commitment to reduce UK greenhouse gas emissions by at least 80% by 2050 (compared to 1990 levels), in the Climate Change Act 2008. Today, around 60% of emissions come from electricity, heat production and travel. Environmental concerns, including emissions, are also central to the waste industry although waste produces a relatively small proportion of total greenhouse gas emissions (less than 5%).¹

Progress has been made. Between 1990 and 2016, emissions from energy supply decreased by 54%, mainly thanks to changes in the fuels used to generate electricity and reductions in energy demand. Emissions from waste management have dropped by 73%.²

The Paris Agreement on climate change marks a further shift in the level of agreed global ambition, despite the USA's recent announcement on withdrawal. More than 170 countries have established renewable energy targets by themselves, and nearly 150 have enacted policies to encourage investment in renewable energy technologies.³

It is possible to create low carbon energy and waste infrastructure systems. The challenge is to do it at a cost which is acceptable to those who need to use them. Energy is key to all economic activities. It is therefore absolutely essential that businesses and consumers are able to continue accessing services at an affordable price. The more cost-effective the UK's strategy, the more likely it is to influence the actions of other countries. Low cost, low carbon is the best contribution that energy can make to an industrial strategy.

The Committee on Climate Change estimates that policies to counteract damaging climate change will add £200 a year to a domestic consumer's energy bill in 2030, up from around £100 today.⁴ Given the pressures on household and business budgets, these costs need to be reduced as far as possible. Research carried out on behalf of the Commission demonstrates that domestic consumers' chief concerns about energy are related to cost. Energy bills are perceived to be very expensive and constantly increasing, and people expect this to get worse.⁵ Government needs to focus resolutely on how to "go green at low cost".

In the waste sector, consumers are concerned by the growing amounts of packaging waste generated by an increasingly 'disposable' society.⁶ Wasteful packaging is a key issue on which the Commission will report in the final Assessment.

Next steps

The Commission's modelling projects that energy demand in the UK will fall by between 8-12% by 2035 and 6-15% by 2050.⁷ This compares to Government projections of an increase in demand of 2-13% by 2035.⁸ The change in waste by 2050 is projected to be between a 1% fall and a 46% increase.⁹

Low carbon infrastructure needs to harness leading-edge technology. As the UK is a world leader in digital systems, its infrastructure systems and their users should benefit from this expertise.¹⁰ Achieving system-wide changes can be more difficult in infrastructure sectors than elsewhere in the economy.¹¹ However, there are large potential benefits that the UK needs to exploit in order to minimise overall costs to consumers. Efficiency gains could also be achieved by improving building insulation and making appliances more efficient.

The costs of some energy technologies, renewables and batteries in particular, have fallen substantially. The capital cost of wind turbines has fallen by nearly a third since 2009 and photovoltaic solar panels by 80%.¹² The spread of these technologies provides a huge opportunity to create a low carbon system more cheaply than was thought possible even two or three years ago.

The rise of electric vehicles represents another opportunity to reduce the emissions from infrastructure. Transport accounted for 26% of total UK emissions in 2016.¹³ As carbon dioxide emissions from electricity generation fall, the benefits from switching to electric vehicles increase. Removing the pollution that the internal combustion engine creates also brings big air quality benefits, especially in cities and towns. Electric vehicles are discussed in more detail in chapter 5.

The electricity system needs to evolve rapidly to adapt to the challenges posed by the switch to lower carbon generation and large-scale use of electric vehicles. The Commission's *Smart Power* report outlined some of the initial steps that will need to be taken to achieve this, but there is potentially a wider role for technology to help maximise the efficiency of the system and reduce its overall cost.

The Commission's *Smart Power* report

Smart Power, published in March 2016, set out the Commission's recommendations to Government to ensure that the electricity system is fit for the future. The report looked at the changing power sector and the opportunities that arise as a result of creating a more flexible system using interconnection, storage and demand flexibility.

- *Interconnection* – better connections to the UK's network from countries with cheap, green power supplies, such as Norway and Iceland.
- *Storage* – exploiting the UK's opportunity to become a world leader in energy storage technology, by creating a level playing field between generation and storage.
- *Demand flexibility* – using technology to allow consumers to save money and cut emissions without inconvenience.

Smart Power's recommendations to Government and regulators aimed to ensure action is taken to make the most of these innovative opportunities, removing barriers where they exist and driving change where necessary.

In response to recommendations made by the Commission in the report, Ofgem and the Government published the 'Smart Systems and Flexibility Plan' in July 2017, containing 29 action points.¹⁴ Ofgem has also made a decision on creating a separate 'system operator' company within National Grid.¹⁵

This chapter builds on points raised within *Smart Power*, but does not repeat the analysis and recommendations made by the report.

The main challenges for the waste sector also arise from its environmental impacts. The first is to minimise the need for waste infrastructure. In 2015, households and businesses combined produced almost 50 million tonnes of waste.¹⁶ A more 'circular' economy would see less waste produced in the first place, with more of the remainder reused or recycled. Reducing the quantity of waste is the best way to reduce costs for households and businesses, as well as limiting the environmental impact of waste.

The waste sector has made strong progress in reducing emissions, but there is much more to do. Landfill is the largest source of greenhouse gas emissions from waste, and much of this comes from waste left in landfill historically. The landfill tax has been successful over the last 20 years in encouraging people to make different choices, reducing the percentage of waste collected by local authorities sent to landfill from 80% to 20%.¹⁷ It is unlikely to achieve the same impact over the next 20 years.¹⁸

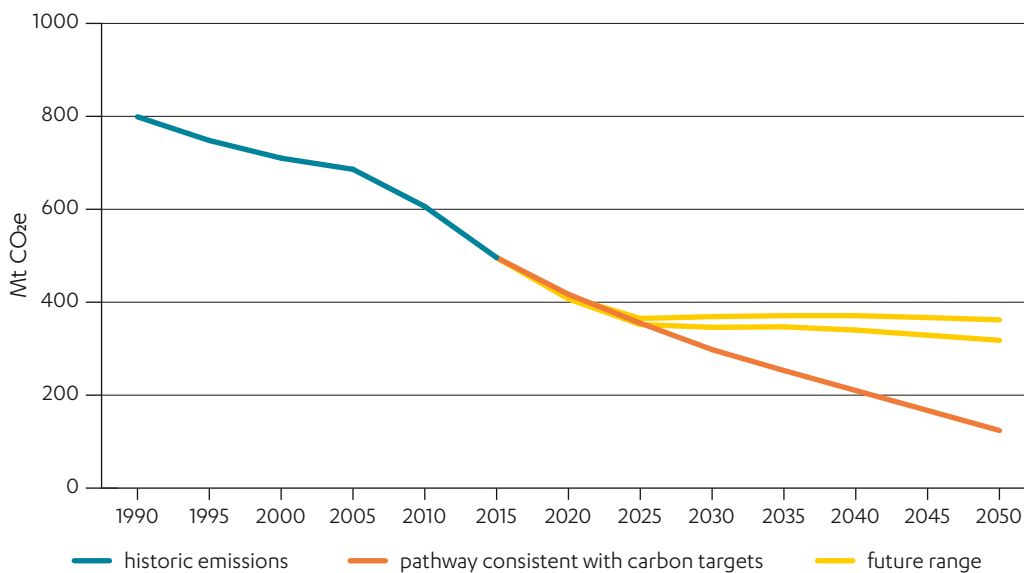
Burning degradable waste such as food and (natural) textiles reduces greenhouse gas emissions, since the carbon dioxide produced is less harmful than methane which is emitted if this is landfilled. However, burning plastics in ‘energy from waste’ facilities increases greenhouse gas emissions, since plastics are carbon-based. Sequestering waste plastics, where recycling is not an option, could reduce emissions compared to incineration but would need to be done in a way that avoided other harmful environmental impacts.

The transition to low carbon infrastructure needs to continue and accelerate over the next couple of decades. The Commission’s modelling results show that without further intervention, the UK will not meet the 2050 targets (see Figure 4.1). The Committee on Climate Change is also clear:

‘Emissions reduction in the power sector alone, or any single sector, will not be enough to meet the ... 2050 target. Furthermore, current policies are not sufficient to continue the good progress to date or broaden it to other sectors.’¹⁹

The Government has committed to addressing this gap through its Clean Growth Strategy. At the time this document was finalised, the Clean Growth Strategy had not been published. Further challenges will emerge beyond 2050. Future Assessments will need to consider these.

Figure 4.1: UK greenhouse gases emissions, assuming no additional policy or regulation aimed at reducing emissions²⁰



Footnote: Annual emissions are based on the Commission’s modelling outputs and calculated as the percentage change on 2015 levels. Further details on the Commission’s modelling are available on the Commission’s website. Although it appears as though the UK will meet its fourth carbon budget, BEIS ‘Updated energy and emissions projections: 2016’ suggest that these targets will not be met without further action.

How things stand

The imperative for a clear policy framework

National carbon reduction targets have been clear and bold, thanks to effective planning by successive Governments in the past 20 years. However, the policies for achieving these reductions have been subject to sudden change.²¹ In the power sector, there are multiple Government interventions across the different markets, with numerous and sometimes conflicting aims.²² It is not clear what level of reduction in emissions, specifically from electricity generation, the Government is aiming for and by when.

Stakeholders have emphasised the importance of greater stability and certainty. In a fast changing world, policy can never offer complete certainty. There are benefits to a flexible approach, where some decisions are taken only once more information is available. But frequent, almost arbitrary changes in policy can create unnecessary costs. The transformation of the energy system needed to meet carbon targets will require very substantial capital investment. If unnecessary uncertainty increases the cost of capital for major projects, then the impact could be very significant.

Where rapid change is expected, a clear framework for setting parameters over time should seek to balance between flexibility and certainty. For example, a medium term pipeline of auctions for 'Contracts for Difference' would provide certainty over the mechanism for allocating support, but allow the price to change with changing circumstances.

'The transition to a secure, affordable and zero carbon power sector is feasible but requires a clear vision from Government and policy makers'.

Institution of Civil Engineers
call for evidence response

How Government encourages investment in generating electricity

Contracts for Difference

Contracts for Difference are designed to support new investment in a wide range of low carbon generation by reducing their need to rely on wholesale electricity prices, which can be volatile. They have previously been awarded through auctions or bilateral processes.

Contracts for Difference require generators to sell energy into the market as usual but, to reduce their exposure to electricity prices, they will be paid a top-up from the market price to ensure they receive a pre-agreed 'strike price'. At times of high market prices, these payments reverse and the generator is required to pay back the difference between the market price and the strike price. This protects consumers from overpayment.

Capacity Market

The Capacity Market offers all providers of electricity capacity (new and existing power stations, electricity storage, and capacity provided by big energy users agreeing to reduce their demand) a steady, predictable revenue stream on which they can base their future investments. In return for income from Capacity Payments, providers must deliver energy at times of system stress, or face penalties.

Potential providers secure the right to receive capacity revenues by participating in a competitive auction process which will set the level of Capacity Payments. The first Capacity Auction took place in December 2014, for delivery obligations that will begin in October 2018.

Contracts for Difference are delivering investment into a pipeline of low carbon generation in the UK. In the case of offshore wind, they are also successfully demonstrating how effective competition can be at driving down costs.

However, where competition has not been used, the lowest possible price has not been achieved. The Competition and Markets Authority has estimated that the *'decision to allocate Contracts for Difference to several projects outside the competitive process in 2014 is likely to have resulted in customers paying far higher costs (approximately £250-310m per year for 15 years) than if the contracts had been awarded competitively'*.²³ Onshore wind farms, one of the cheapest forms of renewable energy, are excluded from the next round of auctions for Contracts for Difference, the Government's current support framework for renewables.

Within the power system, flexibility has been undervalued. Some generators are not paid for services they provide to the system (such as large thermal generation plants, which can help smooth fluctuations) and others are not charged for costs they impose. The market for services that provide flexibility is not a level playing field, which makes it unnecessarily hard for some flexibility services, such as storage and demand-side response, to compete.

The Commission strongly welcomes the Government's recent *'Smart Systems and Flexibility Plan'*, published in response to *Smart Power*, which contains actions to address some of these issues.²⁴ However, ensuring that new technologies are able to participate across the electricity markets needs to be an ongoing area of focus for the Government and regulator.

The UK cannot use natural gas for heating in a low carbon future

The main source of heat in the UK is the burning of natural gas, a process which produces carbon dioxide.²⁵ Without removal of its carbon content, natural gas cannot have a place in a low carbon future. This is the same for the petrol and diesel used in vehicles (discussed in chapter 5).

There is currently no Government vision or strategy for moving to low carbon heat infrastructure, which will be absolutely vital to achieve the UK's emissions targets beyond 2030. No drivers exist for consumers connected to the gas network to change the way they produce heat for buildings, cooking and water. In addition, public awareness of this future large scale change on the horizon is very low.²⁶ The imperative to decarbonise the nation's heating infrastructure will be an important part of the Commission's work in the coming months, and will form a key part of the final Assessment.

What options are there for reducing emissions from heating?

The use of electricity for heating is well established. However, any large scale uptake in the electrification of heat is likely to require increased electricity generating infrastructure and the reinforcement of the existing electricity network. Current peak demand for heat can be between three to four times the current peak demand for electricity.²⁷ A low carbon electricity system would be key to this transition.

Heat pumps are a technology that use electricity to transfer heat from outside a building (even on cold days) to the inside. Because they transfer rather than generate heat, they can be extremely efficient. Widespread use of heat pumps would reduce the impact of electrification of heating on electricity demand, although it would still be substantial. Heat pumps often require extensive modifications within homes and are dependent on high standards of insulation.

Hydrogen could be used as a direct replacement for natural gas, connecting consumers to the gas network, and fuelling boilers and appliances. This would potentially be less disruptive for consumers. Town gas, which was used across the UK before north sea gas, contained around 50% hydrogen. The actual cost of hydrogen as a replacement to natural gas is not clear, however it is likely to be more expensive. This is due to the need for the feedstock materials and the additional infrastructure required to produce greener gas.

There might also be a role for bio-methane produced from waste. However, bio-methane capacity is limited, so it could not be used to heat all the UK's homes.²⁸

The major advantage of these greener gas options is that the gas network could continue to play a role in meeting future energy needs by being repurposed to transport bio-methane or hydrogen. The creation of such a network in the UK could also provide opportunities for vehicles less suited to electrification, such as lorries, to be powered by greener gas.

The cheapest way to make hydrogen is currently through steam methane reformation, which uses natural gas as an input and relies on carbon capture and storage technology, which is not currently in operation in the UK, to remove carbon dioxide.

An alternative to generating heat within homes and offices is the development of heat networks. Heat networks operate by distributing heat produced at a central source e.g. a combined heat and power station or an energy from waste plant, through a network of pipes carrying heated water or steam. Heat networks in themselves are not low carbon. They still need a fuel source. However, in some places they can exploit heat which would otherwise be wasted. In these places, they may be a more efficient solution than directly providing electricity or greener gas. Heat networks work best over shorter distances and lend themselves to densely populated urban areas.

Not enough progress is being made on energy efficiency

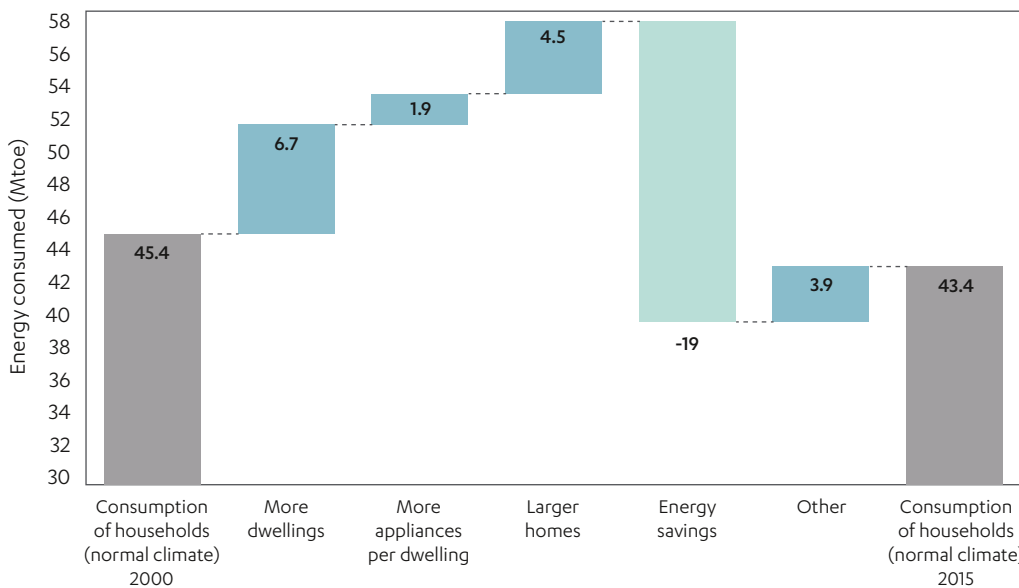
The most important thing that the UK could be doing now to prepare for the transition to low carbon heating infrastructure is to upgrade its building stock. The UK has old and leaky buildings – both residential and commercial.²⁹ This increases the amount of energy needed to regulate their temperature. Most of today's buildings will still be in use when a transition from natural gas needs to take place. It is therefore essential that the demand for energy from these buildings is reduced to help manage this transition.

But progress on improving the energy efficiency of the UK housing stock has slowed. Annual rates of cavity wall and loft insulation in 2013-15 were respectively 60% lower and 90% lower than annual rates in 2008-12.³⁰ There are no plans on the part of the Government to reverse this trend.

Meanwhile, the demand for energy in the home is increasing, as the number of households increases, people buy more appliances and heat larger spaces. Figure 4.2 shows how a large part of the progress made towards saving energy was offset by these factors between 2000 and 2014.

'Increasing efficiency will be key to decarbonising heat for both commercial and domestic consumers. Introduction of higher standards for new buildings should be accompanied by a more rigorous approach to assessing the performance of existing buildings, analogous to the MOT test for a car.'

National Grid Business Development call for evidence response

Figure 4.2: Changes in total household consumption from 2000 to 2015³¹

Energy policy in Scotland, Wales and Northern Ireland

Some aspects of energy policy are devolved across the UK. The Scottish Government has responsibility for the promotion of renewable energy, energy efficiency, and the consenting of electricity generation and transmission developments.³²

Scotland's vision is that by 2050 all buildings will be near zero emissions and that this will have been achieved in an economically and socially sustainable way. Progress to date has included:

- Emissions down 26% against 1990 levels.
- Invested over £650 million since 2009 in energy efficiency and fuel poverty.
- One million energy efficiency measures have been installed.
- The majority of lofts and cavity walls are now insulated.

The Scottish Government continues to review the progress of the scheme, and has been consulting on the next phase. The outcomes of that consultation are expected later this year.³³

The Welsh Government's vision is that energy will be used more efficiently, there will be a reduction in fossil fuel generation and the transition to a low carbon economy will be managed actively.³⁴

The Welsh Government's energy efficiency programmes include:

- The 'Nest' warm home scheme which delivered an average energy bill saving of £400 per household in 2015-16.³⁵

- The 'Arbed' scheme has also been recognised by the Committee on Climate Change as a demonstration of how schemes can deliver wider health, affordability, well-being and regeneration benefits.³⁶

The lessons learned from these schemes should be factored into the future energy strategy for the UK.

Energy policy in Northern Ireland is devolved, with the exception of nuclear energy. It forms part of a Single Electricity Market with Ireland and a substantially lower proportion of homes are connected to the gas network. Nevertheless, decisions taken by the UK Government continue to play an important role given the interconnected nature of policies, markets, systems and infrastructure. The Northern Ireland Executive has set a target for renewables to contribute 40% of electricity supply by 2020.³⁷

Incentives to reduce waste and increasing efficiency

Between 2005 and 2015, household waste per person in the UK fell by 17%. The UK compares relatively well to other European countries. However, some countries such as Sweden, Belgium and Spain waste less.³⁸ With per capita waste at over 400kg per year, there is a need for substantial further reductions. Packaging is an appropriate place to start – for households, packaging represents roughly a quarter of household waste.³⁹

The average amount of energy that can be generated per tonne of waste at most waste plants in the UK is less than one quarter of that of plants in Sweden and Denmark which connect to district heat networks. Many UK plants have the ability to generate both heat and electricity, but only 8 of 37 do.⁴⁰ Too often they are located too far away from places where waste heat might be used (eg housing) and so run at low levels of efficiency, producing electricity only. Burning waste plastics – which are carbon-based – adds to the challenge of climate change by releasing carbon dioxide into the atmosphere, but not all plastics can be recycled.

Better data could help drive improvements in the efficiency and environmental impact of waste treatment. The UK is a leader in the management of data on household waste, but data on commercial and industrial waste is poor.⁴¹ There are concerns about the suitability of the current voluntary electronic documentation system. The Commission will report further on these issues.

The Commission's priorities

Technology

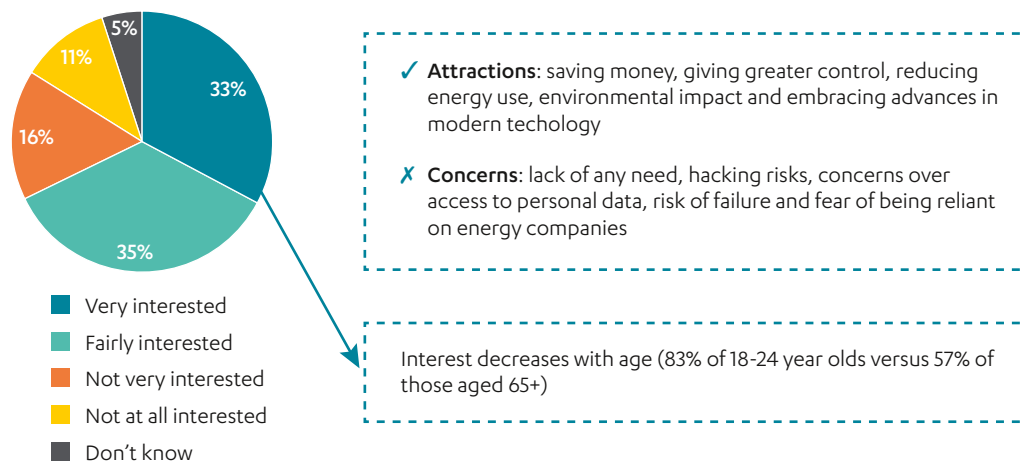
There has been a huge amount of technological change in the energy sector over the past decade. The challenge of creating low carbon energy infrastructure has evolved, from making sure there are enough options to make it achievable, to ensuring that it is done in a value for money way.

Technology can help create a low carbon, smarter and more cost-effective energy system

Using smart technology to manage energy consumption can reduce the demand on the system and make it cheaper to run overall. If less electricity or heat is needed at peak times, there isn't a need for as much overall capacity for producing these forms of energy. In the home, the majority of consumers are interested in using smart appliances. This interest increases amongst younger people (see Figure 4.3).

Figure 4.3: Consumers' interest in using smart appliances⁴²

Interest in using smart appliances in the future



Smart electricity meters are due to be offered to every household and business by 2020, and other 'connected home' technologies such as thermostats and smart appliances are being installed.⁴³ These can assist consumers with decisions and, as technology advances, autonomously adapt to consumption patterns. This will also allow consumers to save money. The Government estimates that smart meters will lead to an increase in bills of £13 in 2016, followed by an average reduction of £11 per year by 2020 and an average saving of £47 per year by 2030.⁴⁴

The energy system could also potentially benefit enormously from technological advances in batteries. The cost of batteries is reducing so much that both electric vehicles and electricity storage are becoming competitive on their own terms.^{44 45} Electric vehicles have the potential to significantly reduce emissions from transport, where little meaningful progress has so far been made. For more discussion of electric vehicle adoption, see chapter 5.

Historically, the UK has generated electricity from large coal, gas and nuclear power stations. As coal is phased out and new sources of low carbon electricity come on stream, electricity infrastructure starts to work differently. Renewable forms of generation can be deployed at varying levels of scale and have different properties and characteristics to the power stations they replace. There may also be physical limits on how much energy the UK can harness from any one particular source. Table 4.1 outlines some of the different characteristics of low carbon electricity generation technologies.

Batteries and other forms of storage are among technologies which have the power to transform this new power system, through making it more flexible and efficient. Others include demand flexibility, interconnection and highly flexible generation plants. The Commission continues to promote the implementation of the recommendations made in the *Smart Power* report, which encourage removal of barriers to these technologies.

Earlier this year, the Hendry review recommended the development of a fleet of tidal lagoons, starting with a pathfinder project at Swansea. The Commission will consider the case for tidal lagoons alongside the full range of other options for meeting the UK's energy needs. Table 4.1 gives an indication of the potential contribution of tidal projects. Any tidal projects must be able to compete on a fair cost basis with other low carbon generation technologies if they are to form part of a low cost, low carbon electricity system.

The Commission will also be considering whether there are unnecessary barriers in place preventing the deployment of onshore wind, one of the cheapest renewable technologies. Onshore wind farms create some costs for local communities. Planning requirements in England already include specific additional hurdles that onshore wind projects have to meet, to ensure community acceptability.⁴⁷ However, unlike offshore wind, the benefits of onshore wind are not being recognised through access to subsidies.

Table 4.1: Characteristics of different electricity generation technologies and energy efficiency in the UK⁴⁸

	Total	Other	Solar PV	Onshore wind	Offshore wind	Nuclear	Gas	Gas with carbon capture and storage	Energy from waste ⁱ	Tidal (range)	Building energy efficiency ⁱⁱ
Installed capacity in 2016 (GW)	96	26	12	11	5	9	32	0	1	0	n.a
Current output (TWh)	339	86	10	21	16	72	129	0	5	0	Saving of >6*
Maximum future annual output (TWh) ⁱⁱⁱ	-	-	140	80	400	208-239*	Not consistent with long term policy objectives	Likely to be large	10-21*	55-66	Saving of 54-57*
Cost in 2016 and 2025 (£/MWh) ^{iv}	-	-	71-94 55-76	48-78 46-74	96-123 58-75	n.a. 85-123	56-58 80-83	n.a. 102-123	25-84 22-80	n.a. 216-368	29*
Carbon intensity (GCO ₂ e/kWh)	-	-	20-73	20-38	9-13	6-26	365-488	20-99	233-257*	10-50	Saving of 210-380
Load factor (%) ^v	-	-	10-11	24-29	36-41	68-78	28-49	n.a	62-69	Assumed to be 20-25	100
Level of intermittency	-	-	Variations within day and across seasons	Some variability within a day and across seasons	Some variability within a day and across seasons	Designed for constant use – current fleet in UK relatively inflexible (depends on design)	Schedulable supply of electricity	Schedulable supply of electricity	Limited to the amount of waste available	Predictable daily tidal patterns	Constant reduction in demand

* Represents an NIC calculation based on available evidence

ⁱ Only accounting for electrical output. Power is not the primary function of Energy from Waste, therefore the power price is not the deciding factor in comparison with other generation technologies.

ⁱⁱ Current annual output figure likely to be higher as these savings only associated with the domestic sector and derived only from ECO and Green Deal improvements. The maximum annual output for Energy Efficiency only considers retrofitting of domestic premises. Carbon savings are assumed to be the offsetting of emissions from a standard gas boiler.

ⁱⁱⁱ In terms of practical resource which could be developed in the UK. This is not a forecast of deployable resource at a specific point in time.

^{iv} These figures represent the Levelised Cost of Electricity (LCOE), which is the best available evidence for comparing costs across technologies. The Commission acknowledges that this doesn't take into account the costs a technology may impose on the system. All estimates are in 2014 real values.

^v The load factor represents the amount of electricity produced over a period of a year divided by the amount of output that would have been produced had it operated at full capacity. This is expressed as a percentage, so that reported load factors lie between 0 and 100. These figures are the historic average annual load factors for 2012 – 2016, with the exception of tidal range.

Improving the efficiency of waste infrastructure

There are a number of possible routes to improving the efficiency of energy from waste facilities and reducing their environmental impact. New plants could be built nearer to sources of demand for heat, such as district heating networks for housing. Plastics could be separated from the waste provided to energy from waste facilities, and sequestered if they cannot be recycled. Food and other degradable waste could be separated from waste for landfill.

Biogas derived from waste could make a positive contribution to reducing emissions from heat and transport where the challenge is greatest, for instance by using it as fuel for lorries or aviation. To do this on a meaningful scale would require further separation of food waste. However, widespread use of biogas could create unintended harm elsewhere – for instance encouraging use of farmland for crops specifically grown for fuel or, worse still, diverting food away from consumers.

New technologies, such as biodigestors, may make separation easier, allowing waste streams to be sent to the most appropriate final disposal option. Gasification projects, currently proven at small scale, also hold the potential to provide bio-hydrogen or biomethane, which could be deployed as an electricity, heat or transport fuel source.

Funding

Energy efficiency: next steps

Energy efficiency measures in buildings are not always appealing to consumers. For some energy efficiency measures up-front costs and hassle can be high.⁴⁹ The payback period from lower energy bills can be longer than the time people expect to stay in their homes. However, increasing the energy efficiency of the UK's buildings would not only save consumers money on their bills straight away, it would also continue to keep heating costs down in the future regardless of the lower carbon forms of heating that may then be used. Some alternative approaches to heating will only work in buildings that have high standards of insulation.

The Commission is examining ways to make the UK's building stock fit for the future. The Government's most recent large scale attempt to promote energy efficiency, the Green Deal, failed to encourage households to improve their homes. Conceived as a finance mechanism to stimulate private investment, Green Deal loans were only taken up by 14,000 households, against the original plan to support millions of homes and businesses. The National Audit Office concluded that the Green Deal was too complex and ultimately less cost-effective in terms of reducing CO₂ emissions than previous schemes.⁵⁰

Energy efficiency: the international picture

Other countries have had success with the implementation of energy efficiency policies and practices. The American Council for Energy-Efficient Economy produce a scorecard of the 23 highest energy consuming nations internationally and review how these nations perform against various energy efficiency metrics. In their 2016 scorecard Germany is identified as the best performing nation for energy efficiency.⁵¹

Through Germany's 'Energiewende' strategy a target has been set of 20% reduction of primary energy consumption by 2020 and a 50% reduction by 2050, compared to 2008 levels. These ambitious goals have been supported by complementary policies and incentives. Energy efficiency in buildings has been promoted via the national Energy Saving Ordinance for buildings established in 2002. This set energy performance standards for new buildings and existing buildings undergoing major renovations. KfW, the state bank, offers long term fixed rate low-interest loans and grants to support energy efficiency in building refurbishments and to encourage new buildings to exceed minimum standards.⁵²

Italy, another high scoring nation, is highlighted as demonstrating best practice in building energy efficiency through an incentive program 'Conto Termico' providing incentives for retrofits and energy efficiency improvements in residential and public buildings.

The National Australian Built Environment Rating System provides energy ratings for commercial buildings based on 'in-use' energy performance rather than predicted energy use. It started as a voluntary scheme and became mandatory in 2011, as take-up increased. Average performance has risen from 2.9 stars in 2000 to 4.2 in 2014 (2.5 represented initial median performance, with 4.5 representing best practice).⁵³

Lowering the cost of providing electricity

Between existing lower cost renewables, nuclear power and technology to remove carbon emissions from burning fossil fuels, there are enough low carbon options available to meet future electricity demand.

The Commission favours the use of existing market mechanisms where possible, to avoid creating more uncertainty. It will therefore consider how Contracts for Difference and the Capacity Market may best be exploited to ensure the lowest cost outcome for consumers, whilst meeting the UK's emission targets.

Well-designed market mechanisms should ideally be open, competitive, technology-neutral and deliver lower cost energy. The Commission wants to consider the following principles and how they might be applied.

'FSB wants to see a strong strategic UK policy direction that provides confidence and security to investors in new energy technologies, including generation, storage and efficiency.'

Federation of Small Businesses call for evidence response

1. Technology neutrality. All low carbon technologies should be able to access the same markets and compete on an equal basis for contracts, as far as possible. New technologies which emerge should be treated on the same basis as existing ones.

2. Optimal length of contracts. No-one knows what the electricity markets will look like in 30 years' time, or what factors will drive the price. The wind and sun are free and new technology to harness their energy means that prices of gas and oil may cease to be relevant. Medium term certainty for investors can lower the capital costs of projects. However, the UK needs to avoid locking itself into a particular market design at this stage. Contract lengths need to reflect the need to retain flexibility in the future development of the electricity market.

3. Equal treatment for small and large generators. Smaller generators currently access different subsidies to larger ones. This differential support is likely to lead to an inefficient mix of generation. While smaller generators may need access to simpler mechanisms to access subsidies, the subsidies themselves could be set to match the clearing price at auctions for larger generators.

4. Cost recovery. There are currently distortions across the system which mean that different types of generators may not pay the costs that they create. All generation and demand should be exposed to the consequences of their actions, and should benefit from reducing or avoiding those impacts. However, the Commission notes that it is likely that managing these costs at system level will be more efficient than each participant doing so individually.

If generators are facing the costs of their impacts, the market would be more effective in investing in the least-cost technologies.⁵⁴ This could result in the trend towards smaller, decentralised generation slowing, if this is imposing extra system cost overall.

'What is important is that the market provides sufficient signals to ensure the most cost-effective solutions are able to be delivered, reflecting scarcity value, flexibility value, long-term infrastructure impacts and carbon emissions. Therefore, while we do not know what the power sector will look like in 2050, it is vital that these two key principles are met:

- All generation and demand should be exposed to identical price signals for any given service, and able to access the same marketplaces at the same value.*
- All generation and demand should be exposed to their full infrastructure and system costs or benefits, including transmission and distribution network costs, considering the long-run (40+ years) infrastructure impacts, and be able to secure the benefits of avoiding those impacts.'*

Association for Decentralised Energy call for evidence response

Making it happen

Whilst the Commission believes that market-based approaches should be used as far as possible, it also recognises that there are some instances where this will not work. The UK might need to draw on some technologies that will not be delivered through a market mechanism. There is a risk that Government prevarication could delay necessary infrastructure being put in place now to achieve 2050 emission targets.

A large scale change in how the majority of buildings are heated in the UK will not happen without new Government policy and support. The Committee on Climate Change report *'Next Steps for UK Heat Policy'* looked at the various technologies available to contribute to reducing carbon emissions and the role that Government policy plays in supporting the transition. This report outlined a possible policy timeline for supporting the transition, including existing and new policies required in the near term and looking out to 2030. The key message is that action is required now if high levels of reductions in carbon emissions are to be achieved by 2050.

The options to generate low carbon heat broadly use one of two methods: using low carbon electricity or shifting to greener forms of gas. The Commission is looking into the relative costs and benefits of different options, as well as the different implications for the wider energy system. Some combination of the available options may be the lowest cost solution. The UK does not necessarily need to choose which route to go down in the short-term, but it will be important to ensure that suitable options remain available in future, when decisions will need to be made.

The Netherlands is facing a similar challenge to reducing heating emissions as the UK. Around 90% of residential heating needs are met with natural gas. The Dutch Ministry of Economic Affairs has published its energy agenda which set out the need for the Netherlands to transition to a low carbon energy sector, including heating, by 2050. Proposed measures include: a commitment to energy conservation; no new gas grids being built for new developments; the replacement of the right to a gas connection with the right to a (technology neutral) heat connection; and the empowerment of local authorities to make decisions regarding the future of heat.⁵⁵ The Commission will consider what lessons can be learned from the Dutch experience.

Nuclear and carbon capture and storage

If electricity is selected as the primary way to heat our buildings in the future, it is unlikely that renewables could generate sufficient electricity to meet total demand. While the cost of renewables is falling, there are physical limits to the volume of electricity that can be generated because of the amount of space that renewables require.

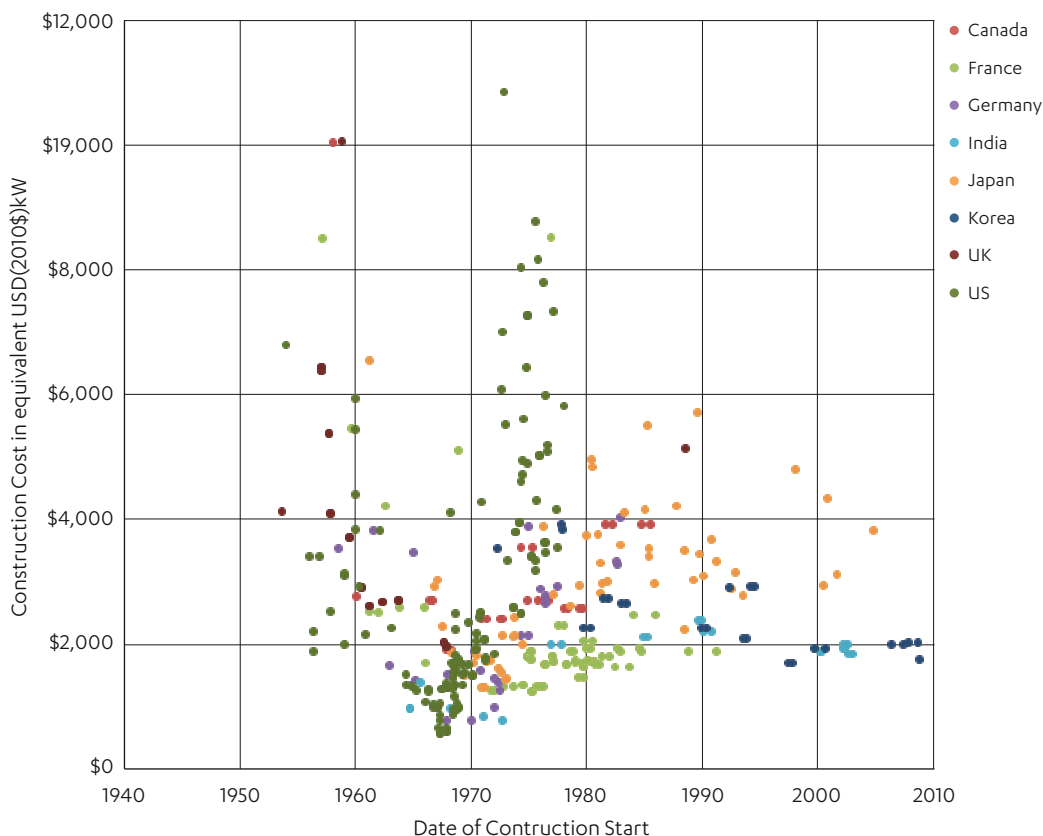
There may also be limits to the proportion of total energy that can be provided by renewables while maintaining system stability. Renewable energy depends on sources such as wind and sunshine that are not always available. Technologies such as storage, interconnection and demand-side response can mitigate these

challenges but at very high levels of renewables it may become very expensive to provide all the flexibility needed.

Nuclear power or carbon capture and storage may therefore be important options. They can potentially complement renewable generation, requiring less physical space and providing benefits for system stability.

Nuclear power faces two particular challenges which mean it will not get built without Government involvement. First, it is an expensive form of generation which requires very high up-front investment. The cost of nuclear power plants is unlikely to become significantly cheaper in the future (see Figure 4.4). Secondly, the financial risks associated with building nuclear power plants are very substantial. Following the collapse of Westinghouse, it is unclear if nuclear power plants will get built in future without some form of Government backing and sharing of risks.

Figure 4.4: Comparison of construction costs of global nuclear reactors in US\$ 2010⁵⁶



Nuclear is low carbon and can play a key role in the electricity system, providing a reliable and stable stream of electricity without the need to burn fossil fuels. However, given the pace of technological change, it is unclear how much new nuclear capacity the UK will need beyond Hinkley Point C. Storage for nuclear waste also remains an unresolved issue in the UK.

Small, modular nuclear reactors might address some of the challenges, in particular reducing the risks of construction. However, there is no reason to believe they would be cheaper than larger plants. None are currently operating commercially anywhere in the world. There may be cheaper options which are worth pursuing, which potentially include carbon capture and storage.

If developed, carbon capture and storage could provide options to reduce emissions across the whole of the energy system. Carbon capture and storage allows for some continued use of fossil fuels such as coal and natural gas. It creates an extra option for reducing the emissions arising from power generation, industrial processes and the manufacture of hydrogen gas for heating and transport fuel. Used alongside biomass, such as woodchips, it could also remove carbon dioxide from the atmosphere ('negative emissions'). This could play a role in offsetting remaining emissions in other areas that are more difficult to tackle, as the UK progresses towards complete removal of emissions from the economy.

Carbon capture and storage has had a difficult history in the UK. Two competitions held by the Government in 2007 and 2012 to develop carbon capture and storage for power generation were both cancelled without delivering a successful project. A National Audit Office report into the second competition process found that the Treasury withdrew the £1 billion funding because they were concerned that the competition would not lead to additional future development and about the future ongoing costs to electricity consumers.⁵⁷

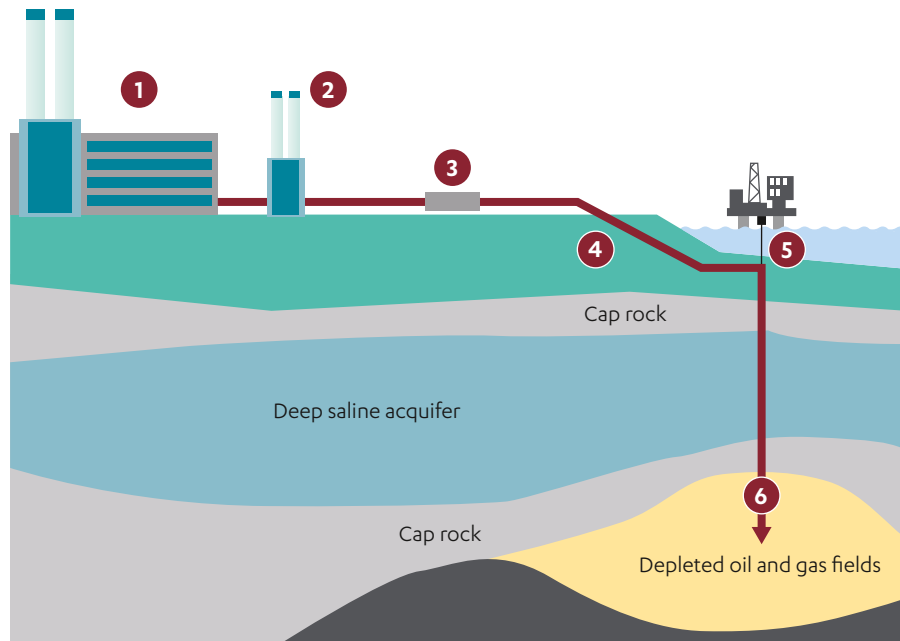
'the widespread deployment of a CCS network allows continued use of gas for power generation, provides the platform for large scale economic production of hydrogen (for power, heat and transport) and offers a route to decarbonising major industrial emitters – overall saving around 1% of GDP per annum.'

The Royal Academy of Engineering call for evidence response

What is carbon capture and storage?

Carbon capture and storage utilises proven technology to capture 90% of carbon dioxide emissions from a source. The carbon dioxide (CO₂) is then transported via pipeline to an injection point, where it is injected into storage sites such as salt caverns or depleted hydrocarbon fields to be stored indefinitely.

Figure 4.5: An illustration of carbon capture and storage attached to power generation



- 1 CO₂ source (eg power plant)** CO₂ is **released** from the burning of **coal** or **gas**, or from elsewhere in the industrial process
- 2 CO₂ capture plant** CO₂ is **removed** from the power plant and **'captured'**.
- 3 Compression unit** In the compression unit, the captured CO₂ is **compressed** into liquid for **easier transportation**.
- 4 CO₂ transport** The compressed CO₂ is then **transported**, usually via purpose-built **pipelines**.
- 5 CO₂ injection** At the offshore storage site, the CO₂ is **injected** into a carefully selected geological formation, usually **dense porous rock**.
- 6 CO₂ injection** After injection, the CO₂ moves up through the storage site until it reaches the **impermeable layer** of rock above the storage site. This layer of rock acts as a **'seal'**, preventing CO₂ from escaping.

The United States has led the way with carbon capture and storage, with the first project operational in 1972. Of the 17 projects which are operational globally, 9 are within the US, with others in Norway, Canada, Brazil, Saudi Arabia and the United Arab Emirates.

Operational applications of carbon capture and storage include power generation and hydrogen production. In the majority of cases the carbon captured is used in enhanced oil recovery, rather than being stored indefinitely.

Most projects have received some sort of support from state organisations, through financial grants. In some cases parts of the project are wholly owned by state organisations.⁵⁸

Although proven technically, the risks associated with the delivery of carbon capture and storage infrastructure have been widely reported to be too large for private investment to bring forward without Government support. The National Audit Office believe that 'it is currently inconceivable that carbon capture and storage projects will be developed without Government support.'⁵⁹

The Commission wants to understand whether Government intervention to create a network, or parts of a network, is justified by the flexibility that would be provided by making options available for carbon capture and storage.

The Commission held an expert roundtable to examine the need for carbon capture and storage in the UK. There was agreement that initial projects should be located in one of four key industrial regions: Merseyside, Teesside, Humberside and the Firth of Forth. These areas lend themselves to the development of carbon capture and storage as they have sources of carbon for capture, and are close to areas suitable for the storage of carbon.

Stakeholders in the carbon capture and storage industry also identified the potential for repurposing some North Sea oil and gas equipment to provide a backbone for the transport and storage infrastructure needed to store captured carbon in the North Sea. If re-use is possible, this could avoid some of the anticipated costs of decommissioning oil and gas infrastructure and help minimise the cost of carbon capture and storage.

The National Audit Office recently recommended that the strategic case for nuclear power should be periodically reviewed.⁶⁰ The Commission will be considering the strategic cases for both nuclear power and carbon capture and storage over the coming months, and will make recommendations to Government in the final National Infrastructure Assessment.

Reducing waste from packaging

Promoting behavioural change and managing down demand in a reasonable way are as relevant to waste as energy. Sustained behavioural campaigns, such as that led by the Waste and Resources Action Programme (WRAP), to manage demand are central to cost-effectively meeting our infrastructure needs. Incentives are also key.

Extended producer responsibility schemes seek to make the producers of waste responsible for the environmental costs of disposing of their products at the end of their life. Schemes currently apply to packaging, batteries, vehicles and electrical equipment.

The 'packaging recovery note' system covers packaging waste. It uses a market-based approach to minimise the cost to businesses. It is based on recycling rates, but only partially rewards the prevention and reduction of packaging waste. While the system is supposed to provide a market incentive to increase the rate of recycling, empirical evidence suggests this link is weak.⁶¹

In fact, much of the success of the packaging recovery note system appears to depend upon the supporting policies of recycling targets, the voluntary Courtauld

Commitments on reducing waste and the landfill tax. One recent policy success has been the carrier bag levy, which within 6 months of introduction is estimated to have reduced single carrier bag use by more than 70% in large retailers.⁶² Any future policy could look to harness these small-scale financial incentives.

The Commission's vision

The Commission's vision is for the UK to have abundant low cost, low carbon energy, far less waste and more efficient, sustainable treatment of the residual waste.

The Commission believes it is possible to achieve these goals. In particular, the successful exploitation of the falling costs of low carbon technologies will ensure energy prices are as low as possible, underpinning a strong industrial strategy.

Recommendations as to how to bring this about will form a key part of the 2018 National Infrastructure Assessment.

Questions for consultation

The UK has an established and mature gas grid, which provides a reliable supply of gas for heating. However, the continued burning of natural gas for heating is not sustainable as the UK progresses towards a low carbon energy system. This brings into question the future role of the gas grid.

- 13) **What will the critical decision factors be for determining the future of the gas grid? What should the process for deciding its future role be and when do decisions need to be made?**

The UK has a relatively old and energy inefficient building stock, which results in higher energy consumption. Upgrading the energy efficiency of buildings will enable consumers to save money in the short and longer term as the UK switches to low carbon heat infrastructure. Building refurbishment could be integrated with other enhancements, such as installing solar panels or alternative forms of heating.

- 14) **What should be the ambition and timeline for greater energy efficiency in buildings? What combination of funding, incentives and regulation will be most effective for delivering this ambition?**

Keeping the cost of low carbon energy down is one of the most important inputs into a successful industrial strategy for the UK. Well-designed market mechanisms should ideally be open, competitive and technology neutral.

- 15) **How could existing mechanisms to ensure low carbon electricity is delivered at the lowest cost be improved through:**

- Being technology neutral as far as possible
- Avoiding the costs of being locked in to excessively long contracts

- **Treating smaller and larger generators equally**
- **Participants paying the costs they impose on the system**
- **Bringing forward the highest value smart grid solutions?**

Nuclear power is an expensive form of generation and is unlikely to get built without Government intervention. However, if electricity is selected as the primary way to heat our buildings in the future, it is unlikely that renewables could generate sufficient electricity to meet total demand. It is also unclear whether system stability can be maintained with very high levels of renewables.

- 16) What are the critical decision factors for determining the role of new nuclear plants in the UK in scenarios where electricity either does, or does not, play a major role in the decarbonisation of heat? What would be the most cost-effective way to bring forward new generation capacity? How important would it be for cost-effectiveness to have a fleet of nuclear plants?**

Carbon capture and storage has the potential to support the transition to a low carbon energy system in multiple ways, including enabling the creation of greener gases for heating, and reducing emissions for fossil fuel power stations and industry. However, it has had a difficult history in the UK. Internationally, it is predominantly used for enhanced oil recovery, rather than reducing carbon dioxide emissions.

- 17) What are the critical decision factors for determining the role of carbon capture and storage in the UK in scenarios where electricity either does, or does not, play a major role in the decarbonisation of heat? What would be the most cost-effective way to bring it forward?**

Waste can be a valuable fuel for the difficult-to-decarbonise sectors. New and established technologies could make a contribution to the heat and transport sectors.

- 18) How should the residual waste stream be separated and sorted amongst anaerobic digestion, energy from waste facilities and alternatives to maximise the benefits to society and minimise the environmental costs?**

The first best option to reduce waste costs for households and businesses is to minimise the amount of waste produced. The packaging recovery note system places costs on the producers of packaging to account for the end-of-life impact.

- 19) Could the packaging regulations be reformed to sharpen the incentives on producers to reduce packaging, without placing disproportionate costs on businesses or creating significant market distortions?**

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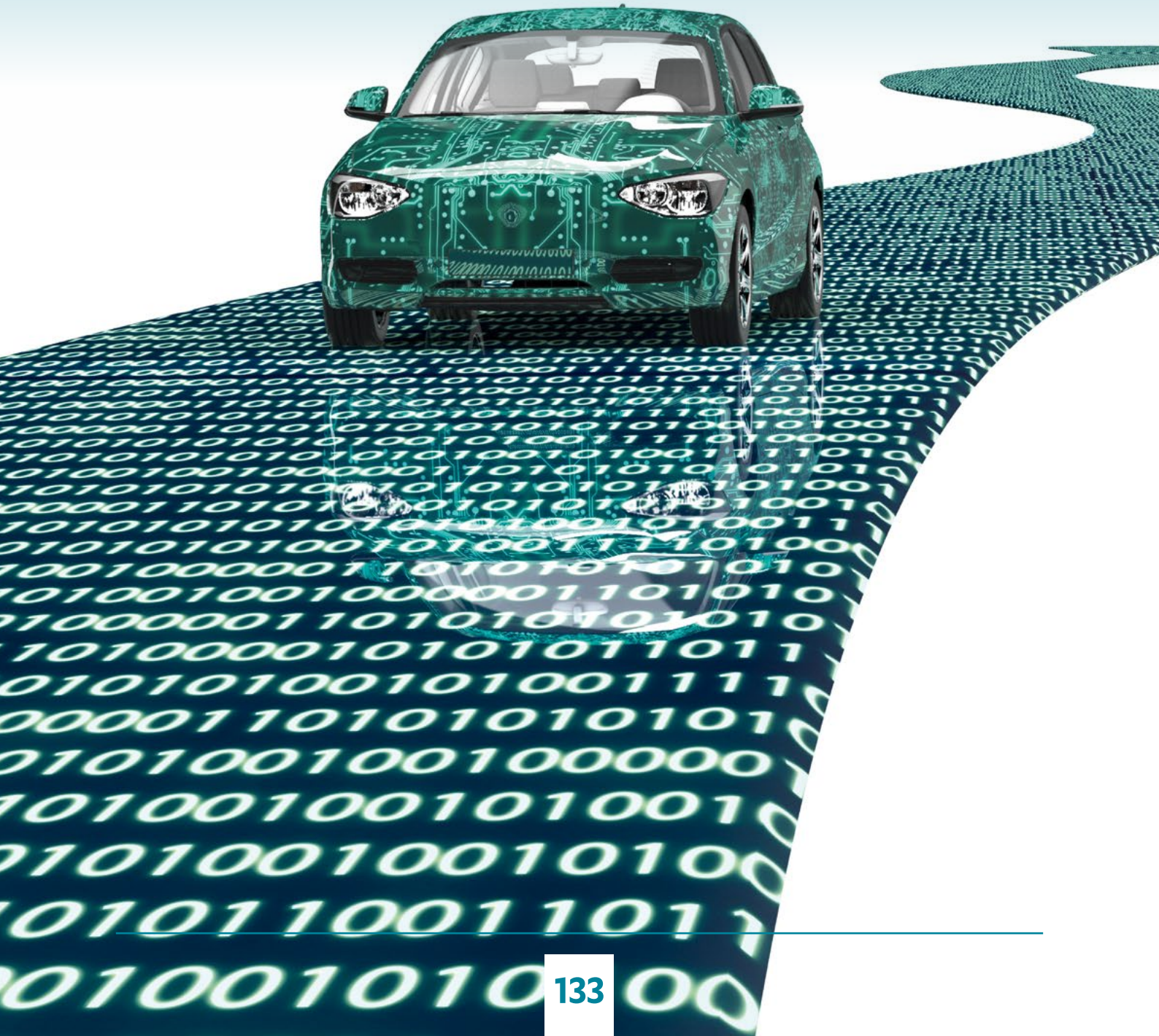
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5. A REVOLUTION IN ROAD TRANSPORT



ROAD TRANSPORT IS ABOUT TO UNDERGO A REVOLUTION:

Vehicles contribute to

80%

of air pollution breaches and 26% of greenhouse gas emissions



Electric, connected and autonomous vehicles will make travel cleaner, safer and more comfortable. Self-driving cars could be on the road by the 2020s.



BUT, ACTION IS NEEDED TO REALISE THE BENEFITS

There is only one charging point per

2,900

vehicles



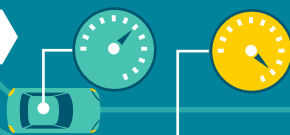
Managing demand with smart chargers could save

£8 billion

in electricity network upgrades by 2050

HOW MIGHT ROADS CHANGE TO GET THE MOST FROM CONNECTED, AUTONOMOUS VEHICLES?

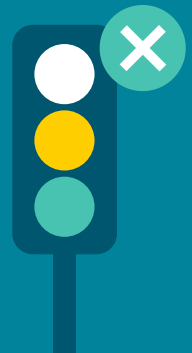
1



Higher speed limits with safer cars?

2

No more traffic lights: cars interlace automatically at junctions?



3

No more overtaking: cars all travel at the maximum speed?

4

Platooning vehicles in a dedicated lane?



5

Changing lane directions in morning and evening rush hours?

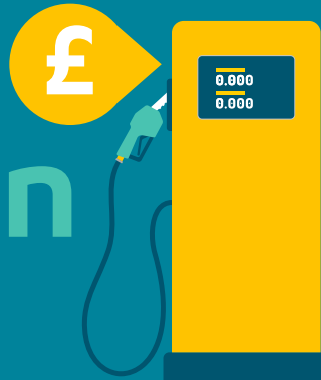


THERE HAS TO BE A NEW WAY OF TAXING MOTORING

Fuel duty raises

£27billion

Electric vehicles
won't pay it

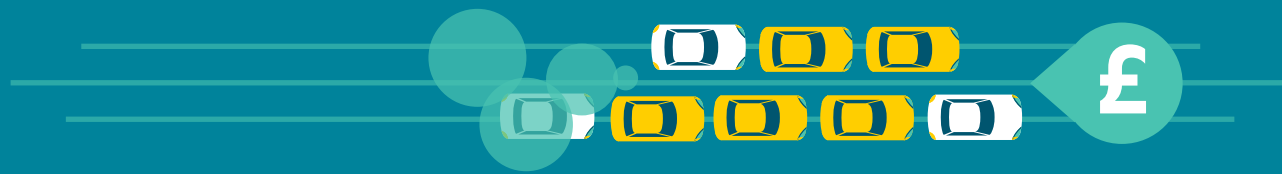


A new system could

price congestion

The London congestion charge immediately reduced congestion by

30%

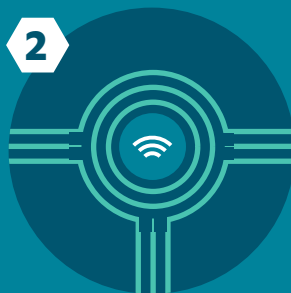


A Better Future



Smart charging points

available for a fleet of electric vehicles



Smart, flexible roads

able to adapt to connected and autonomous vehicles



New pricing system

that charges road users fairly for the trips they make and helps to reduce congestion

Sources: Defra, BEIS, DfT, ETI, TfL, Zap Map

The need for action

Most journeys in the UK are made on the road. After 100 years of incremental change, road transport is about to undergo a revolution. A new generation of electric, connected and autonomous vehicles will offer higher quality, safer, and less polluting travel.

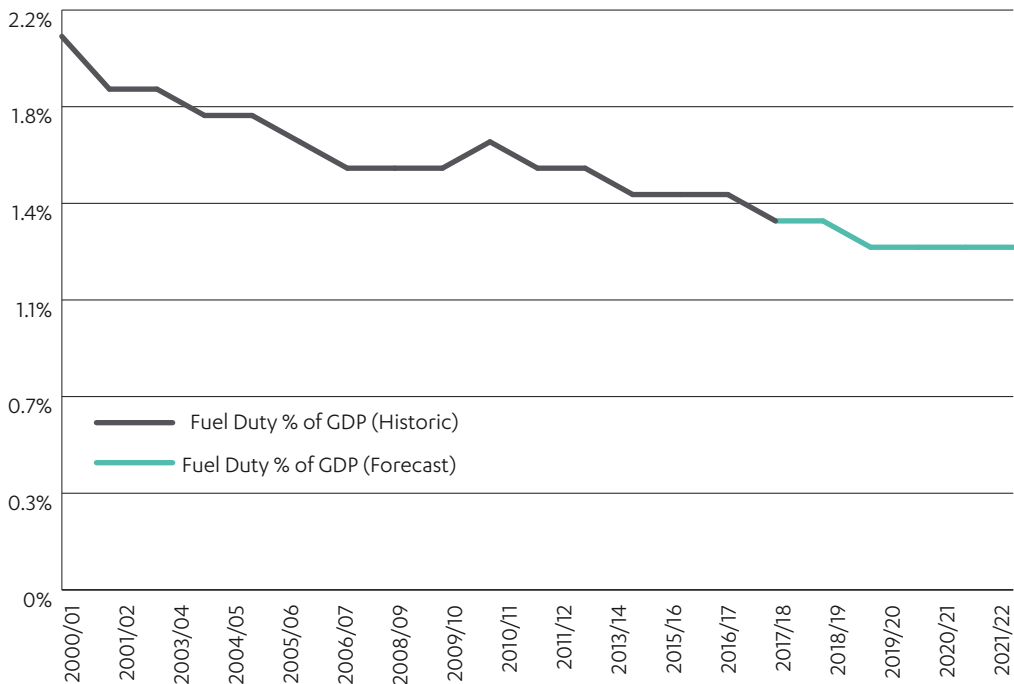
Electric vehicles will change the approach to transport in the UK. The focus in recent years has been on environmental concerns about road use, in particular greenhouse gas emissions, air pollution and noise. Electric vehicles can radically reduce all of these problems. The recent Government announcement on ending the sale of all new conventional petrol and diesel cars and vans by 2040 is welcome.¹ The Mayor of London will require all newly licensed taxis to be zero emission capable from 2018.² The Commission welcomes this too.

The UK's target to reduce greenhouse gas emissions by at least 80% of 1990 levels by 2050 will only be met if nearly all vehicles on the road run on low carbon power or fuels. The Committee on Climate Change, who recommended the 2050 target, noted that improvements in the efficiency of petrol and diesel vehicles 'will not themselves be sufficient to reduce carbon emissions to the extent needed'.³

However, a fully electrified vehicle fleet, and the UK's targets for reducing greenhouse gas emissions, will not be delivered without robust action. Similarly, the full benefits of connected and autonomous vehicles will not just happen. Both will require changes in road infrastructure and how people use the road. The Government needs to be planning for this now.

Realising these benefits also means finding a new way of taxing road use. Fuel duty currently raises more than the total roads budget.⁴ The Government has stated that spending on national main roads will at least match revenues from vehicle excise duty from 2020/21.⁵

If the UK meets its greenhouse gas emissions targets without changing the tax system, Fuel Duty and Vehicle Excise Duty would fall towards zero by 2050. Revenue from fuel duty has already fallen as vehicles have become more efficient (Figure 5.1). Taxes on road users would no longer be sufficient to cover the costs of enhancing and maintaining the road. The 2017 Wolfson Economics Prize winner proposed replacing fuel duty and vehicle excise duty with a distance-based charge, that also captures road and environmental impacts.

Figure 5.1: Fuel duty as a % of GDP, 2000-2022⁶

Finding a replacement for fuel duty provides an opportunity to cover all the costs of road use. Electric, connected and autonomous vehicles will increasingly address environmental and safety issues. It would be a missed opportunity to think about a new way to pay for roads without thinking about the last piece of the puzzle, congestion. This primarily occurs in and around urban centres where economic activity is intensive and road space is limited (see chapter 2).

Connected and autonomous vehicles, even if there is still a driver at the wheel, will make road travel more comfortable, less stressful and safer. Fully driverless vehicles would also open up new opportunities for travel among people who cannot readily drive at present, including the young, the elderly and the disabled. This may be particularly important in rural areas, where alternatives to cars are more limited and where a disproportionate share of older people live.

Both car manufacturers and technology companies are investing large sums in developing connected and autonomous vehicles. Existing technology can already control the vehicle in a wide range of circumstances and is increasingly being deployed within cars on the market today.

The roll-out of digital connectivity along roads, recommended in the Commission's *Connected Future* report, will be crucial for realising these benefits, in particular the benefits of connectivity between vehicles.⁷ Digital infrastructure is discussed in more detail in chapter 1.

Car manufacturers are predominantly focused on building future cars for existing roads. However, making the most of these new technologies is likely to require changes in the nature of the road and road use.

The right changes to the road and road use will take detailed investigation. Some will inevitably involve trade-offs between different road users and differing objectives, which will require public debate about what is acceptable. A key question will be whether it is acceptable, at some future date, to constrain parts of the network only for vehicles with a level of connectivity and automation which allows more coordinated driving patterns, just as motorways already exclude certain road users. Some of the issues that might arise between now and 2050 include:

- ‘Platooning’ of vehicles, where the gaps between vehicles are much smaller than in normal traffic, which substantially reduces energy use. UK trials are already planned for lorries.⁸ One option would be for platoons to use the outside lane. This would require changes to overtaking rules, since lorries are still likely to go slower in some conditions, eg up steep hills, even if vehicle speeds are coordinated.
- Overtaking behaviour and the allocation of lanes for overtaking. Vehicles travelling at different speeds creates a great deal of complexity on the road network, requiring additional road space and creating the risk of accidents and congestion. Future cars might all travel at the same speed, improving the efficiency of road use and reducing the need for ‘overtaking’ lanes, which would allow multiple lanes to be repurposed.
- Changes to how vehicles flow through junctions, a key cause of congestion. Connected vehicles may be able to interlace at junctions so as to flow more efficiently, without the need for stopping and starting (eg at traffic lights). This in turn may have implications for how junctions should best be designed and potentially save money where pinch points only occur because of driver behaviour.
- Speed limits, which could potentially increase to reflect much higher safety standards of future cars. It will be important to understand the noise and energy implications of any higher speed limits. Energy use rises rapidly at higher speeds.
- Dynamic lane re-allocation where there are strong ‘tidal’ flows. Some parts of the network see heavy use at certain times in one direction, but much lighter use in the opposing direction. In future, it may be possible to re-allocate the direction of some lanes, to increase effective capacity, with connected vehicles being able to manage this more complex environment without an increased risk of accidents.

Connected and autonomous vehicles may also lead to new models of vehicle ownership and use. With fully driverless vehicles, people who are not able to drive themselves at present (such as the elderly or disabled) would be able to get around by car, and it may no longer be necessary to find a parking space near a passenger’s destination as vehicles park themselves after they drop off their passenger. In urban areas, automated on-demand public transport options could be explored, providing more convenience than buses or trams but using road space more efficiently than individual cars.

What are connected and autonomous vehicles?

While closely linked, there are a number of distinctions between ‘connected’ and ‘autonomous’ vehicles.

Connected vehicles can communicate with other vehicles or infrastructure on the road network. This allows innovations such as ‘platooning’, where a driver-controlled lead vehicle is electronically linked to other vehicles following behind. The connected vehicle concept is about supplying useful information to a driver or a vehicle to assist with safer and better informed driving. There has not yet been mass adoption of network connected vehicles.

Fully autonomous vehicles do not require a human driver, using a range of systems (for instance sensors and computer processing) to navigate the road safely. There are a range of possible levels of automation, with reducing need for human involvement and ultimately full automation. Technologies that automate driving tasks are already used in vehicles on the road today, for instance parking assistance, lane control, automatic collision avoidance and adaptive cruise control.

On-street trials of connected and autonomous vehicles have been taking place in Greenwich (the GATEway project led by TRL), Milton Keynes (the LUTZ Pathfinder Project led by the Transport Systems Catapult) and Bristol (the Venturer Project), with others planned in 2017 in Coventry and London.⁹

Singapore has begun trials on public roads last year, mostly in low traffic areas.¹⁰ A European Commission co-funded project, CityMobil2, trialed the use of autonomous public transport vehicles for local journeys in seven cities between 2012 and 2016.¹¹

Automotive companies in the UK – such as Jaguar Land Rover and Nissan – are delivering the innovation that will allow for increasingly sophisticated connected and autonomous vehicles. Predictions about the pace of mass adoption of fully autonomous vehicles vary, but most in the industry consider it to be inevitable in the longer term. Before that end point is reached, increasingly connected vehicles may result in benefits sooner for road capacity, safety, environment and providing information and entertainment for passengers, as well as helping to pave the way towards fully autonomous vehicles.

How things stand

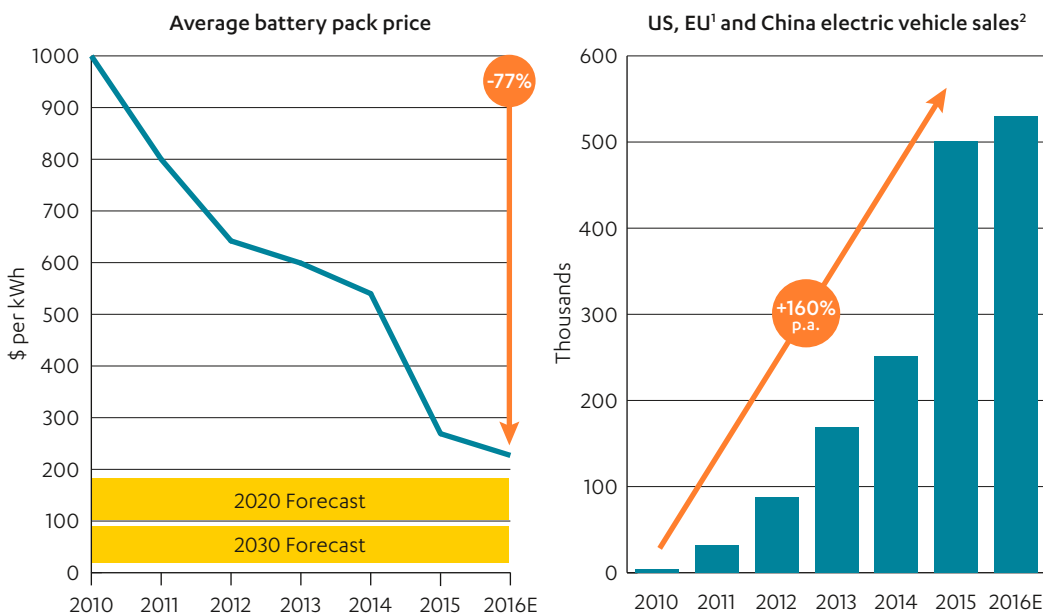
Reducing the environmental impacts of road use

The environmental impacts of road transport are severe. It accounts for nearly 80 per cent of the nitrogen dioxide pollution responsible for breached legal limits.¹² Transport can also lead to high concentrations of dangerous particulates (microscopic airborne particles that can enter the lungs), especially in urban areas. Particulates arise from using diesel fuel but also from brake and tyre wear and road abrasion.¹³ Transport is also responsible for about 26% of all UK domestic emissions of greenhouse gases, with cars and light goods vehicles by far the biggest contributor.¹⁴

The Government released its plan for tackling roadside nitrogen dioxide concentrations in July 2017. A more comprehensive Clean Air Strategy is promised for 2018.¹⁵ The plan leaves most anti-pollution measures to be dealt with by local authorities, with some additional central funding. Breaches in nitrogen dioxide limits are location specific and some local measures, such as redesigning road layouts, are inherently local. However, the underlying cause of roadside air pollution is the make-up of the UK’s vehicle stock. A comprehensive approach would require action at both central and local Government level.

Vehicle manufacturers have made significant progress on the performance of both hybrid and fully electric vehicles. Electric vehicles are more efficient than petrol or diesel vehicles, so the overall energy required to power them should be lower (depending on how the electricity itself is generated).¹⁶ Development of battery technology is increasing the distance that can be travelled between charging and reducing costs, making electric vehicles increasingly attractive to consumers (Figure 5.2).

Figure 5.2: Battery prices and electric vehicles sales in the US, EU and China¹⁷



¹ Includes Denmark, France, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, and the UK

² Plug-in hybrid electric vehicles and battery electric vehicles; excludes low-speed vehicles and hybrid electric vehicles without a plug

Hybrid vehicles potentially offer a bridging technology, allowing shorter journeys to be fully electric but providing greater range when needed. However, the size of the benefits will depend on consumer behaviour, in particular whether drivers maximise the use of battery power, only using the internal combustion engine as a fall-back.

The pace of change towards electric vehicles is accelerating, reflecting a common ‘S’ shaped pattern in the diffusion of new technology. Motor manufacturers are increasingly looking to electric or hybrid vehicles as the bulk of their future ranges. Increased research and development efforts will further improve performance and lower costs, driving up demand in a positive cycle.

Both France and the UK have now announced their intention to ban sales of new petrol or diesel cars by 2040.¹⁸ However, with the right conditions, change could happen much sooner.

Given current industry momentum and falling costs, it looks like electric vehicles will capture the market for low emission vehicles in the short to medium term. History demonstrates that this is likely to create lock-in effects in their favour.¹⁹ This would have negative impacts on the uptake of alternatives, such as hydrogen vehicles, which are promoted by some as a credible alternative to electric vehicles, as well as existing petrol and diesel technologies. The Commission believes that for the foreseeable future, it is electric vehicle technology that will displace the internal combustion engine in cars and vans and policy should be focused on promoting this shift.

The UK needs to promote this shift to electric vehicles: the opportunity is huge. However, not enough is being done to encourage it. The 12,000 public charging points available at present amount to only one per 2,900 registered vehicles, compared with one per 350 in Norway.²⁰ Among driving licence holders, the most important factors putting them off buying an electric car or van are recharging and the distance travelled on a battery.²¹

The Commission welcomes the tabling of the Automated and Electric Vehicles Bill to empower the Government to set standards and require motorway services and large fuel retailers to install electric charging points.²² The Government has also announced 'a further strategy on the pathway to zero emission transport' to be published by March 2018.²³ To take advantage of the opportunity of electric vehicles, this will need to ensure the best solutions are implemented in different locations to provide a comprehensive national charging network.

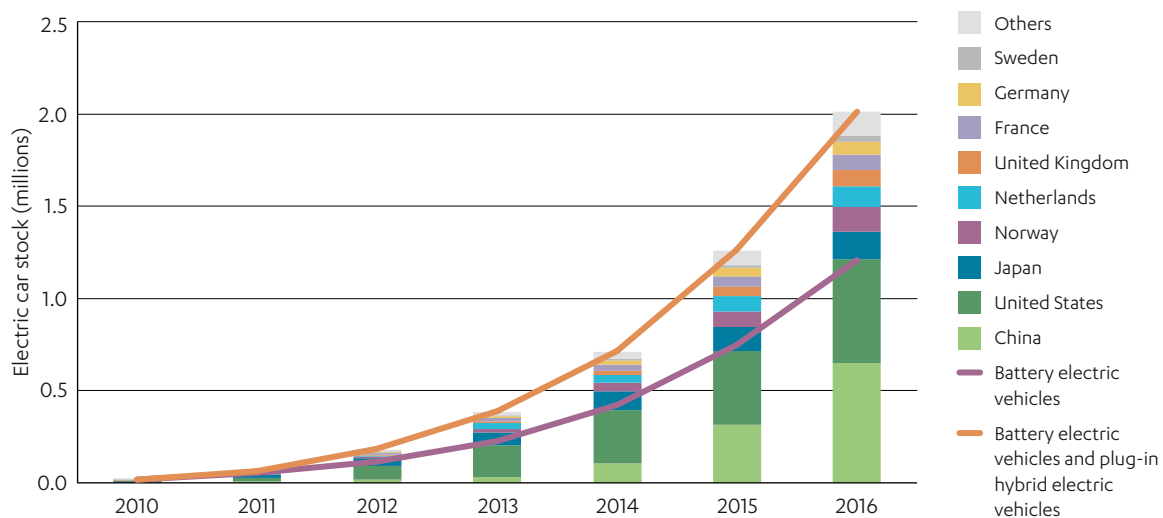
'Fast charging infrastructure (with output up to 350kW) may require significant infrastructure investment to support; therefore, understanding the likely development will be a key input into future planning.'

UK Power Networks call for evidence response

International comparison of electric vehicle adoption

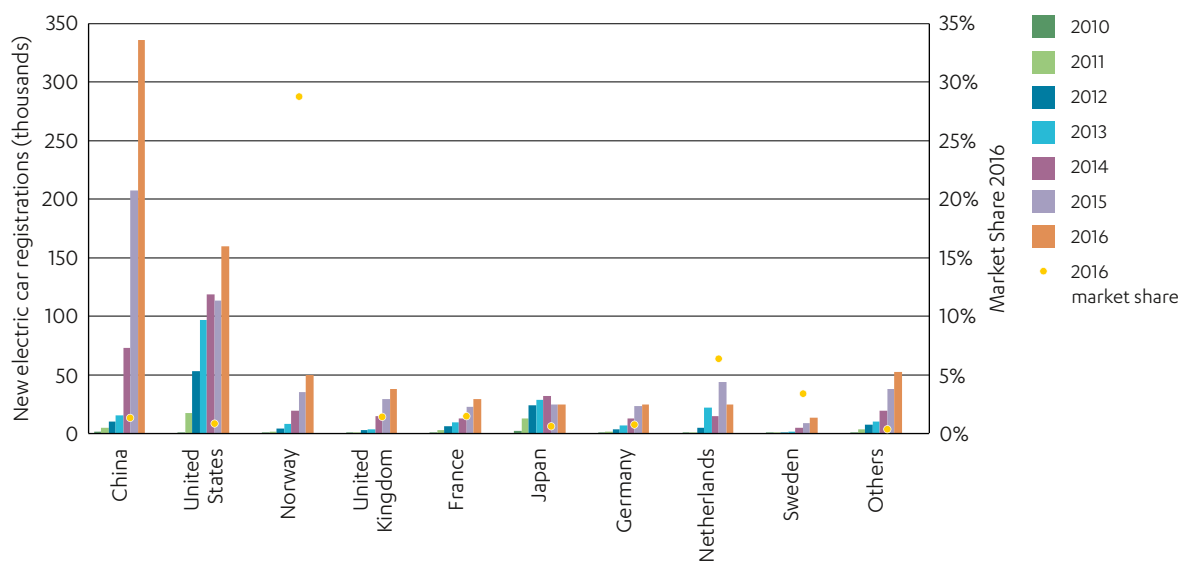
In 2015, electric vehicles accounted for just a tiny fraction of the global vehicle stock (0.1% for cars), but sales rose above 1% of all new vehicle registrations in seven countries: Norway, the Netherlands, Sweden, Denmark, France, China and the United Kingdom.

Figure 5.3: Evolution of the global electric car stock 2010 - 2016²⁴



China and the United States account for more than half of all electric cars on the road worldwide. However, the leading countries in terms of market penetration are found in Europe, in particular Norway, the Netherlands and Sweden.²⁵

Figure 5.4: Electric vehicle sales and market share in a selection of different countries and regions, 2015²⁶



Norway

Electric vehicles now account for nearly 30% of vehicle sales in Norway. The country has the highest ownership of electric vehicles per person anywhere in the world, with electric vehicles making up 5% of all vehicles at the end of 2016.²⁷

Although Norway benefits from cheap hydroelectricity, take-up has also been strongly encouraged through a mix of financial and non-financial incentives. These include VAT, registration tax and toll road exemptions; reduced annual vehicle licence fees; bus lane access; free parking; and the delivery of an extensive charging network.²⁸ Over 8,600 public charging points are available across the country.²⁹

Exemption from high purchase taxes applied to conventional vehicles means that the purchase price of the fully electric Nissan Leaf is now similar to that of a Volkswagen Golf with a 1.4 litre petrol engine.³⁰

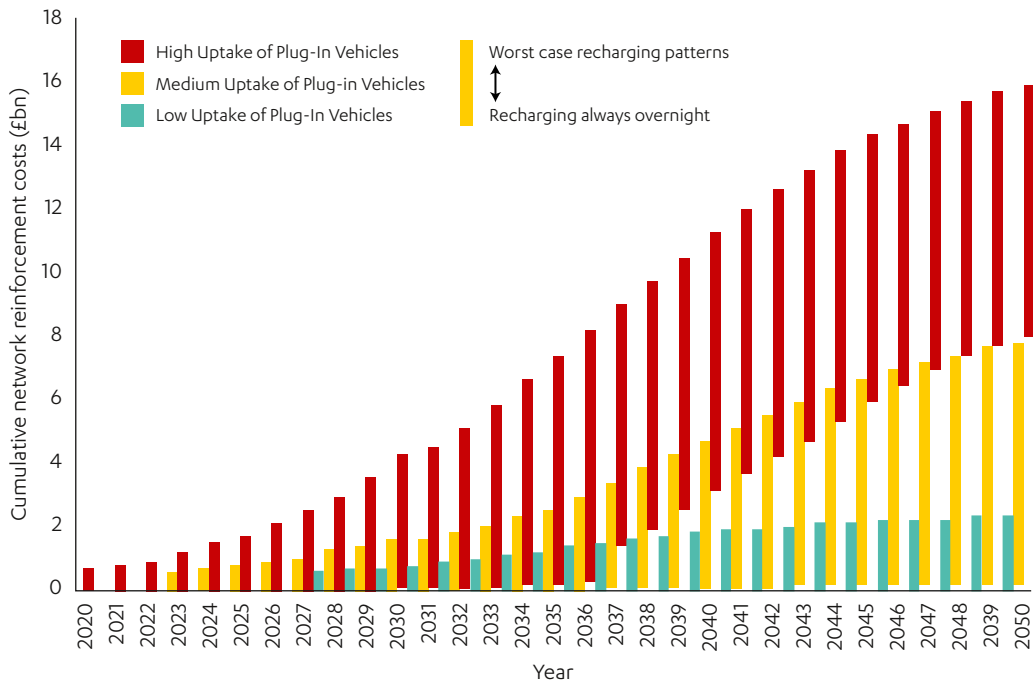
China

China is quickly becoming the largest market for electric vehicles, surpassing the United States in 2015. It plans to deploy five million electric vehicles by 2020. The Government is offering multiple incentives on purchase such as exemption from acquisition and excise taxes. China is also leading the global deployment of electric bus fleets, with more than 300,000 electric buses already operating today.³¹

There is no plan at present to manage the impact of electric vehicle adoption on the electricity network. The Commission estimates that electrifying half of the current car and light goods vehicle fleet would increase average annual electricity demand by around 13% from its current level.³² The Low Carbon Vehicle Partnership have estimated a 16% increase for a comparable level of uptake.³³

Recent analysis by National Grid highlights that the impact on electricity peak demand will depend heavily on charging patterns. Peak demand will drive the amount of extra electricity generation capacity required. Across their scenarios, the increase in peak electricity demand for electric vehicle charging varies between 6GW and 18GW in 2050 (compared to around 60GW today). Sensitivity analysis suggests an extreme case (including more electric vehicles on the road and 20% of people charging at peak time) could be as much as 30GW.³⁴

Consumer behaviour will be a key factor in the cost that electric vehicles impose on electricity networks. Unchecked, users are likely to plug their cars in at home when they return home, which is typically when electricity demand is near its peak. Unmanaged simultaneous electric vehicle charging at peak times will put an additional strain on an already stressed distribution network, potentially requiring costly reinforcements (Figure 5.5).

Figure 5.5: Impact of charging patterns on network reinforcement costs³⁵

‘Evidence to date suggests that the more widespread charging of electric vehicles could have a significant impact on the distribution network with potentially high costs to absorb the new load. This is because charging of electric vehicles unless managed is typically concentrated in the evening, coinciding with the household peak demand.’

Northern Powergrid call for evidence response

Smart charging infrastructure, which can interact with the electricity distribution network to manage these pressures, would reduce both reinforcement costs and the level of extra generating capacity required. In most cases, it should be possible for electric vehicles to charge at times when electricity demand is relatively low, such as in the middle of the night. Few vehicles will require fully recharging on a daily basis, since most journeys are short (commercial vehicles and taxis would be exceptions).³⁶ Smart chargers could also pause charging to allow for other high demand household appliances (such as kettles) to operate without blowing household fuses. But this will not simply happen: an integrated strategy for smart charging is needed that meets the needs of vehicle owners and the electricity network.

High capacity grid connections will become increasingly important for locations with a need for multiple charge points, such as bus garages, ambulance stations and freight depots. Providing high capacity charging in convenient locations such as office, supermarket and commercial car parks might be at least a partial substitute for home charging, requiring fewer, higher capacity, upgrades to distribution networks which could prove cheaper.³⁷

Current regulatory barriers to electric vehicle take-up also need to be addressed. Using low emission light goods vehicles for last mile deliveries in cities will be increasingly important in improving air quality. Current regulations, which are based on vehicle weights, penalise electric vans since batteries are heavy, meaning electric vans can only carry lighter loads. The Government is consulting on options to address this.³⁸ It is important that this leads to action.

There is uncertainty over whether electricity will be able to fuel heavy goods vehicles, given their weight and need to travel long distances. Tesla recently announced work on an electric heavy goods vehicle prototype.³⁹ Biofuels or hydrogen may prove better options. However, sources of sustainable biofuels are limited (waste, covered in chapter 4, is the most important) and there are other competing potential uses, including shipping and aviation.⁴⁰ The viability of hydrogen will depend in part on whether it is also used for heating (see chapter 4). It is too early to draw conclusions at this stage. In particular, the UK cannot go it alone: vehicle markets are multi-national and any solutions will be developed at European or global levels. This is an issue that future Assessments will need to consider once there is greater clarity on likely options.

Congestion

Traffic congestion is increasing, particularly in and around major cities (see Chapter 2). The European Commission reported in 2012 that out of 20 European countries, the annual cost of traffic congestion was highest in the UK. The country was joint second worst when that cost was measured as a proportion of GDP.⁴¹

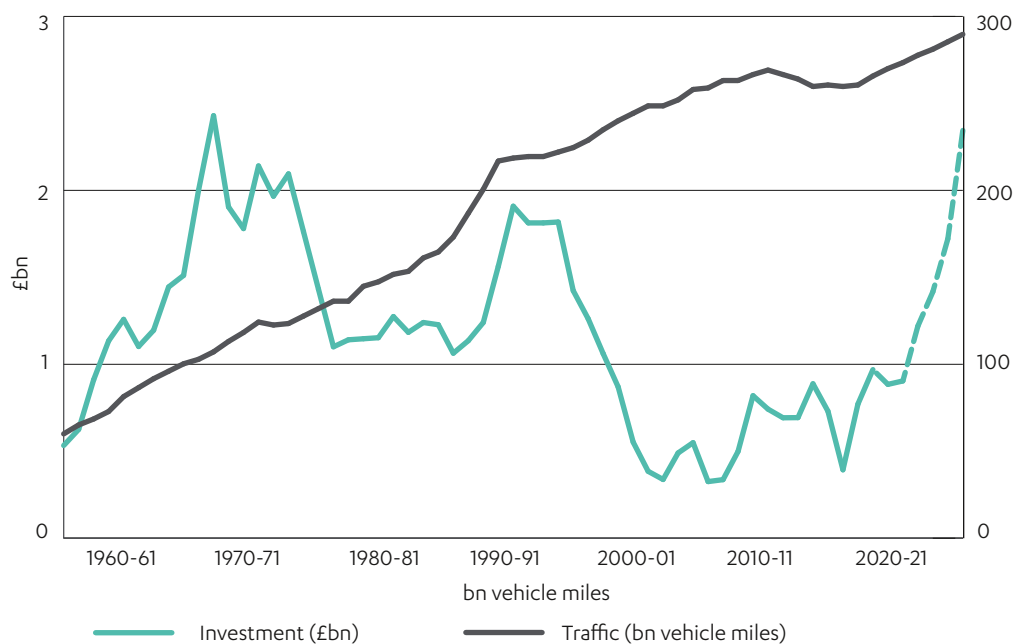
Analysis for the Government suggests that connected and autonomous vehicles could use road space more efficiently and increase the volume of traffic that can be accommodated.⁴² However, by offering more comfortable journeys and new travel opportunities, they are also likely to increase demand to use the road. Traditional means of controlling road use, for example by restricting the availability of parking or increasing its price, may become less effective if vehicles increasingly drive themselves and therefore do not need to park near the destination of their passengers. Evidence to date suggests that encouraging the use of communications technologies, such as video-conferencing, as a substitute for travel is unlikely to prove effective.⁴³

It is not possible for the UK to build its way out of congestion. Especially in urban areas, where most congestion occurs, new roads lead to new journeys, filling up the additional space.⁴⁴ People take advantage of the new capacity to make different choices of where to live and work, and when to travel, rather than reducing congestion. The most effective strategy to manage congestion is pricing. The Mayor of London recently proposed enhancements to the existing London congestion charge.⁴⁵ Durham has a road user charge zone and Nottingham has a workplace parking levy. However, elsewhere, the congestion pricing debate is stalled while congestion continues to increase.

Maintaining and enhancing the roads

In 2013 the Government set out a medium-term approach to major road funding, with a Road Investment Strategy covering the period from 2015-2020.⁴⁶ The funding covers the strategic network of national main roads managed by Highways England, which carries around one third of all traffic and two thirds of freight. The Government is currently developing a further strategy for the period 2020-2025. These are welcome initiatives compensating for years of under-investment (Figure 5.6).

Figure 5.6: Investment in major road schemes and road traffic⁴⁷



However, 98% of the UK's road network, carrying two thirds of all traffic and including many important rural and urban 'A' roads, is managed by local authorities. Funding is increasingly being constrained – local authorities have faced average budget cuts of 26% in real terms since 2009-10.⁴⁸

These cuts have impacted on maintenance programmes and local roads are increasingly in poor condition. Estimates of the current maintenance backlog range up to £11.5 billion.⁴⁹ This is similar to the Government's total spending on all roads each year.

Maintenance is likely to become an increasingly important issue given the effects of climate change. Without further action to improve monitoring of the condition of roads, the need to fix problems after they have occurred will increase. This can be twenty times less cost-effective than preventative maintenance.⁵⁰

The road network needs to be understood as a system, with journeys using a mix of local authority and strategic roads. However, there is no coherent strategy to support local authorities in addressing these challenges.

Connected and autonomous vehicles

Both car manufacturers and technology companies are investing large sums in developing connected and autonomous vehicles. However car manufacturers are mainly focusing on building future cars for existing roads, and relatively little work has been done on how the roads themselves should be adapted. The work that has been done has also tended to focus on short-term requirements, highlighting for example the need to enhance road signage and traffic signals.⁵¹

Work on short-term changes is clearly important as there is likely to be a lengthy transition period when more autonomous vehicles will need to share the road with the existing vehicles. However, more focus is needed on the best long-term outcome for road infrastructure to maximise the benefits of a fully driverless and connected world, and what needs to be done to make that happen.

The opportunity to enable more intelligent and intensive use of roads looks promising, particularly on major roads. Motorways and trunk 'A' roads are relatively self-contained environments, free of barriers and the need for difficult manoeuvres. On urban roads, challenges such as interaction with pedestrians and cyclists need to be overcome and benefits may also be limited by congestion.

In the 1930s new forms of road, such as the Pennsylvania Turnpike, started to emerge in response to the shift from horses to cars.⁵² The same thinking needs to occur today to take advantage of the car of the future. The Government will also need to provide leadership to address the complex policy, legal and insurance issues which will arise.

The Commission's priorities

The UK needs to make the right choices now to maximise the benefits of technological changes that will transform the way roads are used, and to replace the current system of paying for roads with a new approach that covers all the costs of road use, including congestion.

Technology

Major improvements in digital connectivity along roads will be crucial for enabling connected vehicles. This was recommended in the Commission's **Connected Future** report.⁵³ Recent research highlights that benefits from the use of these vehicles depend on them being able to identify each other on a road network shared with conventional vehicles.⁵⁴ Digital infrastructure is discussed in chapter 1.

Technological enhancements such as smart motorways, automated traffic light management and the provision of real-time information to motorists can enhance traffic flows without the need for expensive physical enhancements to road capacity.⁵⁵

Technology can also help reduce the costs of road maintenance. Sensors embedded into the infrastructure, or carried on vehicles, can monitor the state of the road

in real time. Machine learning can use this data to identify where failure is likely to occur and target maintenance where it has the highest value, rather than waiting for failure. New techniques for road works could improve the quality and longevity of repairs.

The adoption of electric vehicles requires the rapid roll-out of a smart charging network that extends beyond highly populated areas and is appropriate to local needs. This includes options where no off-street parking is available (for example on-street or lamppost-based charging), and rapid charging in the right places to enable longer journeys. The right mix of home-based and other charging needs to be considered, reflecting the costs of electricity network upgrades and consumer behaviour, in particular potential new models of car ownership. Putting sufficient charging infrastructure into new housing and commercial development now can avoid costly retrofitting later. Rural areas, where average road journeys are longer and commercial deployment may be slower, will need sufficient provision.

As prices fall, demand for electric vehicles could rise sharply but only if suitable charging infrastructure is in place.

Electricity requirements will need to be considered, as will the impact on electricity distribution networks, and storage opportunities offered by electric vehicle batteries. Improvements in air quality would be immediate. Chapter 4 considers how the UK's electricity generation can be provided from low carbon sources to ensure this also leads to reductions in greenhouse gas emissions.

Smart technologies and managed solutions to co-ordinate charging patterns can ensure vehicles are charged when needed while reducing the need for costly electricity network reinforcement. Smart technology might also allow vehicles to transfer stored energy back to the grid when it is needed. This would help manage local electricity networks and improve stability.

In the next stage of the Assessment, the Commission will consider how to support take-up of electric vehicles and smart chargers. The Commission's new technology study will examine the opportunities from smart traffic control systems.

Funding

The current system of collecting revenue from road users is not sustainable. Any new system to replace fuel duty should include an element of pricing linked to congestion. A modern system of road pricing would lead to quicker, more reliable journeys and reduce the cost of delays. In 2006, the independent Eddington Transport Study estimated the economic benefits could be as high as £28 billion annually, far outweighing any implementation costs.⁵⁶

'We would encourage the Government to coordinate an approach to accessing electric vehicle charging infrastructure that meets the needs of the industry and consumers.'

Energy Networks Association
call for evidence response

A partial road pricing regime already exists for heavy goods vehicles. In 2014, the Government introduced the Road User Levy, a charge between £1.70 a day and £1000 annually, depending on the vehicle type.⁵⁷ The Levy varies with the weight and axle configuration of the vehicle, which affect wear and tear on the road, and with duration, but not with the distance travelled or congestion. A number of European countries also have regimes in place, typically variable tolls or distance-based pricing.

The most recent attempt to start a national debate on road pricing led to significant public opposition,⁵⁸ but the case for it is different today. Government revenue from fuel duty, paid on sales of petrol and diesel, will have largely disappeared by 2050. Without some form of pricing, traffic will increase as Government revenue falls.

Any system of pricing will need to be seen as fair by motorists. At present, the revenue from fuel and vehicle duties exceed the total roads budget.⁵⁹ Many perceive this to be unfair. However, these payments do not reflect the costs of congestion, accidents, air and noise pollution.

A fair system may also need to include compensation or exemptions. For example, a study into proposed congestion charging in San Francisco recommended exemptions or discounts for people with disabilities, on low incomes or resident in the congestion charge area, as well as a daily cap.⁶⁰

Public acceptance is likely to increase if the total amount of revenue collected from road users does not increase, or if the money raised is seen to directly benefit motorists. Data privacy issues will need to be managed effectively. A growing number of people now travel with their driving monitored by insurance companies. This might offer a platform for collecting revenue without the Government ever having access to data on where people have travelled. The use of mobile apps for planning and paying for journeys across multiple transport modes ('mobility as a service') could also provide a platform for road pricing.

Where congestion pricing has been introduced, support for it tends to grow over time. Public consultation should allow respondents the opportunity to experience the change that can be made by a pricing scheme before a final decision on it is made. Trials in Stockholm showed that familiarity with the impact of pricing can help it to become acceptable.⁶¹

Congestion pricing

London Congestion Charge

After its introduction in 2003, the London Congestion Charge led to a fall in the amount of vehicle traffic and delays caused by congestion. The number of cars and mini-cabs entering the zone fell by 33%, and the number of vans by 11%. Congestion – measured by the average time to travel a kilometre – fell from 2.5 minutes to 1.6 minutes.⁶²

Congestion on London roads has since risen, due in part to a significant increase in construction activity, traffic and safety measures and the reallocation of road space for pedestrians, cyclists and buses.⁶³

The Mayor of London's draft transport strategy sets out a range of options to build on the Congestion Charge.⁶⁴

Stockholm Congestion Tax

The tax was first introduced as a seven month trial in 2006. A referendum followed, which led to permanent reintroduction a year later in August 2007. The system has a central cordon around the inner city (35km², nearly 60% larger than London's original charging zone⁶⁵) with a toll charged for crossing it in either direction. The charge is applied to all vehicles, including very low emission vehicles, although these initially received an exemption.⁶⁶

There was an immediate reduction in traffic of 22% crossing the cordon upon introduction. Traffic volumes then rose when the charge was temporarily removed, before falling permanently upon re-introduction. Traffic in 2013 was around 20% lower than in 2005. The fall in traffic volume was highest at peak times, smoothing the pattern of traffic through the course of the day – many more flexible journeys moved to times when the price was lower.⁶⁷

Environmental impacts

In London, kilometres travelled by motor vehicles fell by 211 million per year with a £5 charge and by 237 million with an £8 charge, resulting in a reduction in greenhouse gas emissions equivalent to around 100,000 tonnes of carbon dioxide per year.⁶⁸

Public acceptability

The Stockholm experience highlights the benefit of trialling congestion charging to build public support for the scheme. In Stockholm, the proportion in favour of charging went from 34% prior to first introduction to 72% after permanent introduction.⁶⁹ Support for charging in London has also increased over time. In December 2003, 40% of Londoners were in favour of congestion charging. By 2016, that figure had risen to 48%.⁷⁰

The immediate introduction of a national road pricing scheme would present a huge technical and political challenge. New legislation would be required to implement general road pricing on the strategic road network managed by Highways England. Piloting technology at a smaller scale, such as at the city level, could reduce costs, identify early issues and act as a test bed for innovation. Electric vehicles are currently exempt from motoring taxes⁷¹ but this will need to change as market share increases, providing such an opportunity. Electric vehicles should be exempt from the costs of pollution that diesel and petrol vehicles create, but it would be reasonable for them to pay towards the costs of maintaining and enhancing the road, and congestion. Revenues raised could initially be used to subsidise electric vehicle purchase or charging infrastructure to avoid affecting take-up.

As discussed in chapter 2, congestion pricing zones could also be implemented in and around cities, which would together capture many of the benefits of a national scheme⁷² and potentially pave the way for the creation of one in the longer term. Such zones exist already in London and Durham, but referendums in Edinburgh and Manchester strongly rejected congestion pricing in 2005 and 2008.⁷³ Local authorities already have the power to introduce road pricing on their own road network, subject only to schemes being consistent with local transport plans. Metro mayors should be incentivised to take the lead.

In the next stage of the Assessment, the Commission will consider how road users can pay a fair price for the roads in future.

Making it happen

A clear policy direction and Government leadership on electric, connected and autonomous vehicles could make a major contribution to supporting the UK's Industrial Strategy. Companies such as Nissan are already manufacturing their flagship models here,⁷⁴ and the right mix of policy initiatives from Government would create opportunities for the UK to become a world leader in these fields.

The Government will ultimately need to determine changes in the way roads are planned, designed and operated to maximise the potential benefits of connected, autonomous vehicles. The right solutions will only emerge following proper consideration and debate, covering trade-offs between different road users and objectives.

A key question will be how acceptable it is for individual drivers to give up a degree of control, at least on parts of the road network, in order to improve the outcome for road users as a whole. Some people enjoy driving and may be reluctant to give up control of the vehicle. Others may find it less stressful to hand control over to the vehicle. If vehicles are completely driverless, people may simply value the time available to do other things more highly than time spent driving. But not everyone will share the same point of view.

Making the right decisions for road infrastructure and road use merits further detailed investigation given the complexity and uncertainty involved. Some opportunities arise with technology that already exists in cars on the market today

and does not require replacing the driver, such as automated throttle and steering control. Others are dependent on further technological developments. But that process needs to start now.

In the next stage of the Assessment, the Commission will consider how to get the best from connected, autonomous vehicles.

The Commission's vision

Meeting the Commission's vision would see the UK have:

- Smart, flexible and dynamic road systems which maximise the benefits that a connected and autonomous vehicle fleet present, enabling people and goods to be transported around the country safely and conveniently. Comfortable and stress-free road travel, open to those who cannot readily drive at present, including the young, the elderly and the disabled. Comprehensive and reliable digital connectivity, giving road users access to a full range of information and entertainment services.
- A low carbon vehicle fleet, leading to greenhouse gas emissions from transport being minimised and radical improvements in air quality. Smart charging infrastructure for electric vehicles which communicates directly with the electricity grid, ensuring vehicles are charged when users need them but reducing the need for costly grid upgrades.
- A pricing system which charges road users fairly for the trip they want to make, given road conditions and demand from others to use the road at the same time. This would ensure that congestion is managed efficiently and that roads are paid for fairly.

This future is likely to be possible given the technology currently in use or being tested today. The challenge for Government is that the full benefits of these technologies will not be realised unless robust action is taken. The time to start is now.

Questions for consultation

After 100 years of incremental change in the design and operation of road vehicles, a new generation of connected and autonomous vehicles will offer higher quality and safer road travel. However, car manufacturers are mainly focusing on building future cars for existing roads, and relatively little work has been done on how the roads themselves should be adapted and used.

20) What changes to the design and use of the road would be needed to maximise the opportunities from connected and autonomous vehicles on:

- motorways and 'A' roads outside of cities?
- roads in the urban environment?

How should it be established which changes are socially acceptable and how could they be brought about?

The impact of road transport on air quality is severe, and the Government's greenhouse gas emissions target means that nearly all vehicles on the road will need to run on low carbon power or fuels by 2050. Electric vehicles provide the most promising means of addressing these challenges, but unmanaged charging can put additional strain on the electricity distribution network, potentially requiring costly reinforcements.

21) What Government policies are needed to support the take-up of electric vehicles? What is the role of Government in ensuring a rapid rollout of charging infrastructure? What is the most cost-effective way of ensuring the electricity distribution network can cope?

Meeting the Government's greenhouse gas emissions target means that fuel duty revenue will have fallen towards zero by 2050. Traffic congestion is also a significant and increasing cost to society.

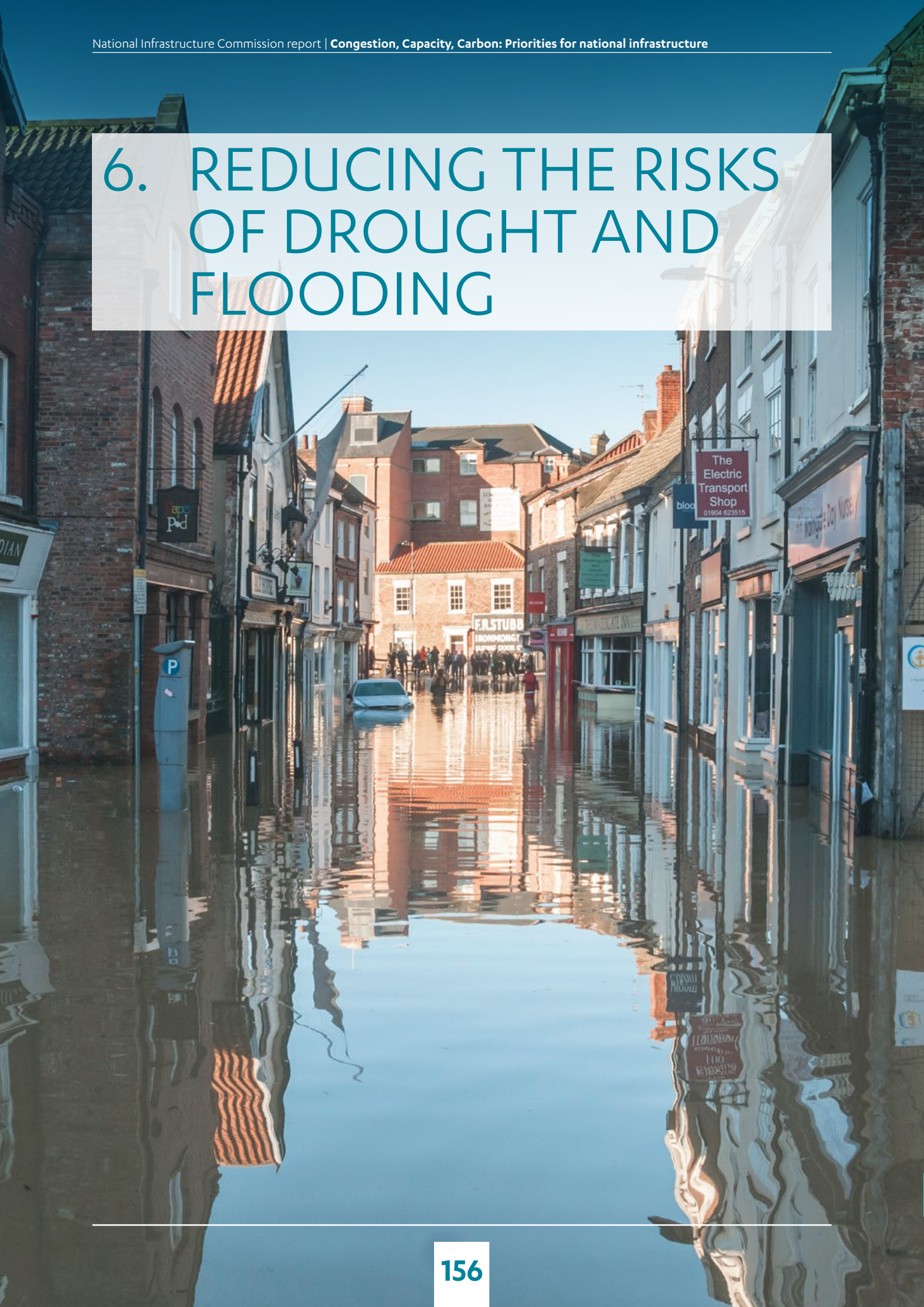
22) How can the Government best replace fuel duty? How can any new system be designed in a way that is fair?

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6. REDUCING THE RISKS OF DROUGHT AND FLOODING



THE UK NEEDS BETTER RESILIENCE AGAINST FLOODING AND DROUGHTS:

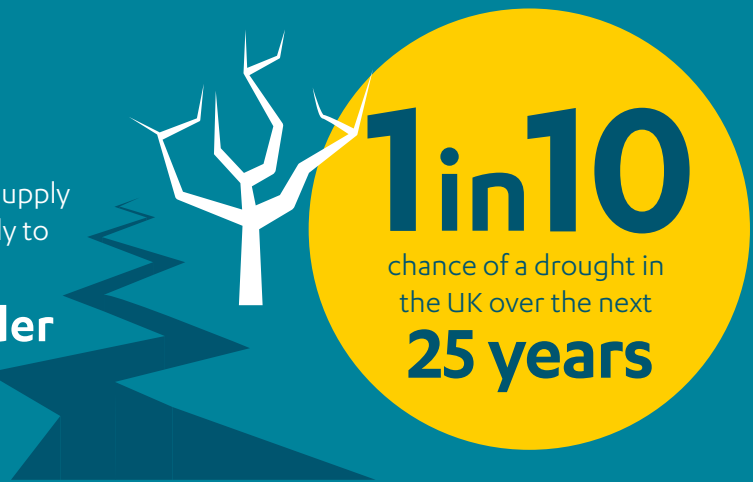
5.2million
properties are at risk
of flooding

Insurance payouts for flooding in Cumbria and the North of England in 2015 were expected to reach

£1.3billion

There is high public confidence in water supply (74%) although households are more likely to be affected by an

emergency drought order
(rota cuts and standpipes) than flooding



PRESSURE ON INFRASTRUCTURE IS INCREASING:

Climate change, a growing population and higher environmental standards are increasing pressures, exacerbated by ageing infrastructure

1

The Commission's modelling indicates that the South East of England will face particularly

significant supply deficits by 2050



2

flood risk will increase by at least

50%

by the 2080s if no action is taken



PROGRESS WITH EXISTING INFRASTRUCTURE HAS BEEN LIMITED:

20%

of water in the public supply is wasted through leaks



Water meters can reduce demand for water by more than

15%

and identify household leakage



The scale of the challenge is likely to require additional water supplies but no major water supply reservoirs have been built since the 1990s

Lack of long-term planning makes it difficult to maintain, replace or build new waste water infrastructure

A Better Future

ACT NOW TO MANAGE FUTURE RISKS

The UK needs to do more than just run to stand still, including:



2

More use of technology

to identify leaks, maintain and optimise networks and encourage customers to reduce demand

1

Better planning

Longer-term and more joined-up planning for flooding, drainage and sewerage to stay ahead of risks



3

Water and flood management infrastructure

that reduces risks and contributes to the environment, including green infrastructure



Sources: Association of British Insurers, Committee on Climate Change, Discover Water, Environment Agency & Water UK

The need for action

Effective water management has important environmental and economic benefits. But water and flood infrastructure is largely invisible in the public eye. Services are often taken for granted despite significant flooding in recent years, fines for sewage pollution and restrictions on water use during periods of drought.¹

Pressure on water systems is growing due to the effects of climate change, increasing population, public expectations and the need to protect the environment. These are combined with ageing infrastructure, uncertain evidence on extreme rainfall and river flows based on relatively short records, fragmented responsibilities across different organisations, and low public and political awareness of the risks the UK faces.

There is clear consensus that these pressures will continue to increase in the years ahead, and that if action is not taken the UK faces a significant risk of damaging droughts and floods. Analysis by Water UK shows that there is about a 1 in 10 chance of the UK seeing a drought event in the next 25 years requiring emergency relief measures such as use of standpipes for two to three months.²

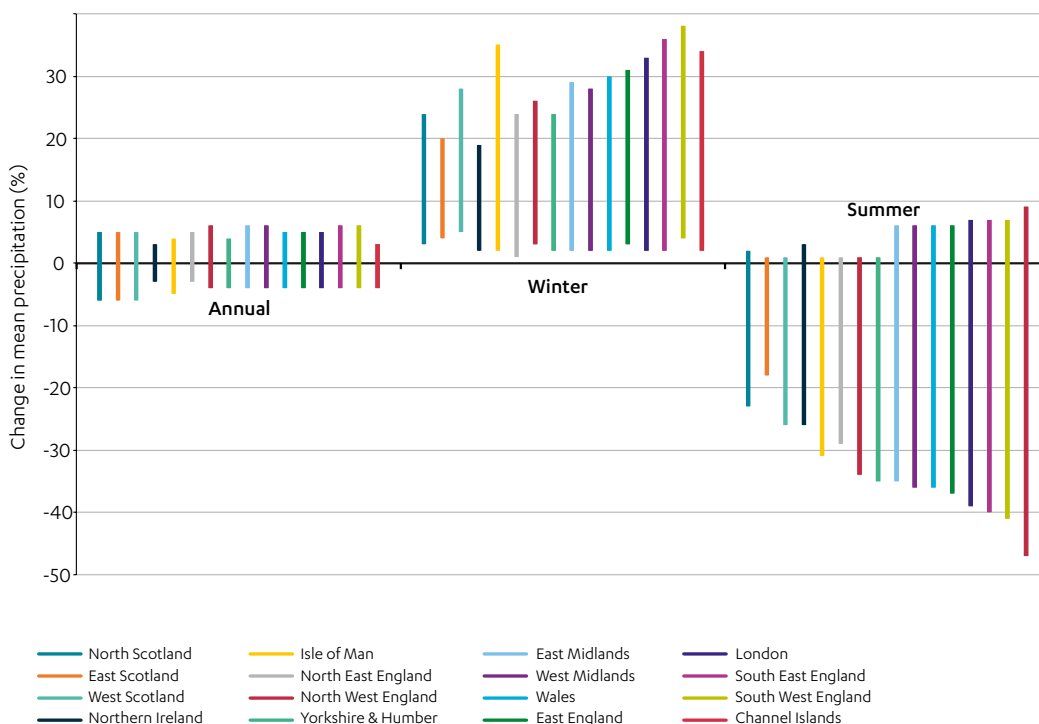
A significant proportion of the nation's infrastructure is in areas at risk of flooding, in part because it needs to be close to rivers or the sea (e.g. for cooling water).³ The Environment Agency estimates that approximately 5.2 million properties in England are in areas at risk of flooding and about 0.8 million have a 1% or greater annual likelihood of flooding from rivers and the sea, with slightly more at a similar risk from surface water.⁴ About 700 properties could be lost to coastal erosion by about 2030. Flooding features prominently in Government assessments of risks facing the UK with river and coastal flooding identified as potentially more severe than surface water.⁵

Risks are already becoming apparent. In 2012, after two dry winters, the South East of England was in danger of a severe drought. This only receded after unusually heavy rainfall in the spring and summer.⁶ The cost of floods has also been significant in recent years. Following storms Desmond, Eva and Frank, which caused extensive flooding in Cumbria and across the North of England in winter 2015-16, the total amount paid out by insurers was expected to reach £1.3 billion.⁷ Sewage discharges damage people's health and the natural environment: the Thames Tideway Tunnel is being constructed after the UK was deemed to be in breach of EU environment law.

Climate change is increasing the risk of both droughts and floods

There is a clear scientific consensus that climate change is already happening.⁸ Globally, the primary impacts on livelihoods and wellbeing are likely to be through water including changes to rainfall patterns and rising sea levels.⁹ As shown in Figure 6.1, projections suggest that in future winters are likely to be wetter and summers to be drier. This will mean an increased risk of both drought and floods across the country, with different effects in different regions.¹⁰

Figure 6.1: Range of change in average annual, summer and winter precipitation for 2040-2069 relative to 1961-1990¹¹



Population growth and environmental factors will exacerbate the pressure

Population is increasing and, together with choices by people about where they want to live, placing further strain on infrastructure.¹² The Office for National Statistics’ central projection is that the UK population will increase by 20% from 64.6 million in 2014 to 77.5 million in 2050. London is projected to grow disproportionately, making up 30% of the UK’s population growth in England until 2039. This increased population will mean greater demand for water and flood risk management infrastructure services.

The amount of water taken for use in homes, agriculture and industry is reducing the quantity and quality of both surface water (rivers and lakes) and groundwater (water accumulated in spaces in soil and rocks). This pressure will be increased by climate change. The UK needs to protect its natural environment, which many infrastructure systems rely on, by ensuring that water is only withdrawn from the environment at a sustainable rate.

The Government is currently reforming the rules for withdrawal of water from the environment. The amount of water that can be taken from rivers and other sources by water companies and other users will in many cases be reduced from current levels. This will help protect the long-term sustainability of water supplies and the aquatic environment that supports them. The extent of these reductions is not yet certain, and unlikely to be finalised before 2019. But the impact is expected to be most significant where the pressures are already greatest. The Water UK Long Term Planning Framework suggests reductions for some companies of between 5 and 50%.¹³

How things stand

The expectations of communities, citizens and customers for the resilience of water and flood management services will be difficult to meet as pressures from climate change, population growth and aging infrastructure start to impact.

Social research conducted for the Commission suggests flood risk is a particular concern for the public, with only 49% of people having confidence in the UK meeting its needs in the next 30 years. Participants supported greater resilience to flooding for people wherever they lived, and were prepared to contribute to funding even where they were not directly at risk. Confidence that needs will be met was much higher for water and waste water, at 74%. Workshop participants suggested this was because safe tap water constantly flowed and bills were less than for other utilities.¹⁴

However analysis of published standards of resilience suggests that more households are at risk of an emergency drought order (requiring rota cuts and standpipes) than are at a similar likelihood of being flooded.¹⁵

Infrastructure systems operate at all scales and span water collection and supply, waste water drainage and treatment as well as flood and coastal erosion risk management. Parts of many current infrastructure systems originally date from hundreds of years ago and have been adapted and extended incrementally.¹⁶ For example the UK still uses water infrastructure originally built in the 17th century and large parts of the sewer system designed by Joseph Bazalgette in the 19th century. Some flood barriers (such as in Hull and York) were built to supplement older river walls which had been raised progressively over time. Much of this infrastructure still functions effectively and represents an enormous legacy from previous generations, but knowledge of some is inadequate, particularly underground networks (such as water pipes or sewers) which are difficult to access.

Low public awareness and a focus on short-term value have constrained action. About 20% of water taken from the environment for public supplies is wasted through leakage.¹⁷ There are shortcomings in asset maintenance and replacement for both water and flood management infrastructure.¹⁸ Water companies and flood risk management authorities do not have a joined-up picture of where infrastructure needs replacing or systems enhancing. Although some infrastructure has been put in place (including expansion of existing reservoirs), no major water supply reservoirs have been built since the early 1990s.¹⁹

There has been limited progress in implementing even 'low regrets' opportunities for increasing resilience and getting the most from the existing infrastructure. For example there has been slow and inconsistent adoption of water meters, which have been shown to reduce demand for water by more than 15% and allow leakage to be identified.²⁰ Flood Re enables access to insurance but does not incentivise resilience for properties at high flood risk (even where it pays for repairs).

'To meet customers' expectations ... water companies must take a long-term view about the reliability of their assets ... and the overall resilience of their systems'

Consumer Council for Water
call for evidence response

Long-term planning, coordination and decision making

Along with infrastructure, institutional arrangements have evolved over time. A wide range of organisations have responsibility for different aspects of water management. Water supply, waste water and flood risk are generally managed separately, even within the same organisation. Each aspect has its own different planning timescales, budgets and procedures, with only limited co-ordination.

Long-term planning for water resources and flood risk management is well established and sophisticated, but discrete plans have been prepared for different types of water infrastructure. Although these involve similar groups of organisations such as the Environment Agency and water companies, the approaches taken are sometimes inconsistent. Better co-ordination could enable more efficient and effective planning and delivery, joining up benefits and requirements across different aspects of water management. For example, there may be more opportunities to use water supply reservoirs to reduce flood risk.

Some water companies have formed regional groups, such as Water Resources South East and Water Resources East, to work across local geographic boundaries and engage with other water users. Water UK (which represents water companies) responded to the Commission's call for evidence for the Assessment highlighting the significance of regional level models that are being used to investigate the "best value" investment approach across a number of water companies. While the Government and regulators recognise the need to consider plans more systematically, it is not clear that the policy and regulatory regime provides sufficient structure, onus and incentives for such collaborative decision-making.

Various system operator models have previously been proposed. System operators could coordinate infrastructure at a regional scale to encourage efficient long term investment plans and approaches such as transfers.

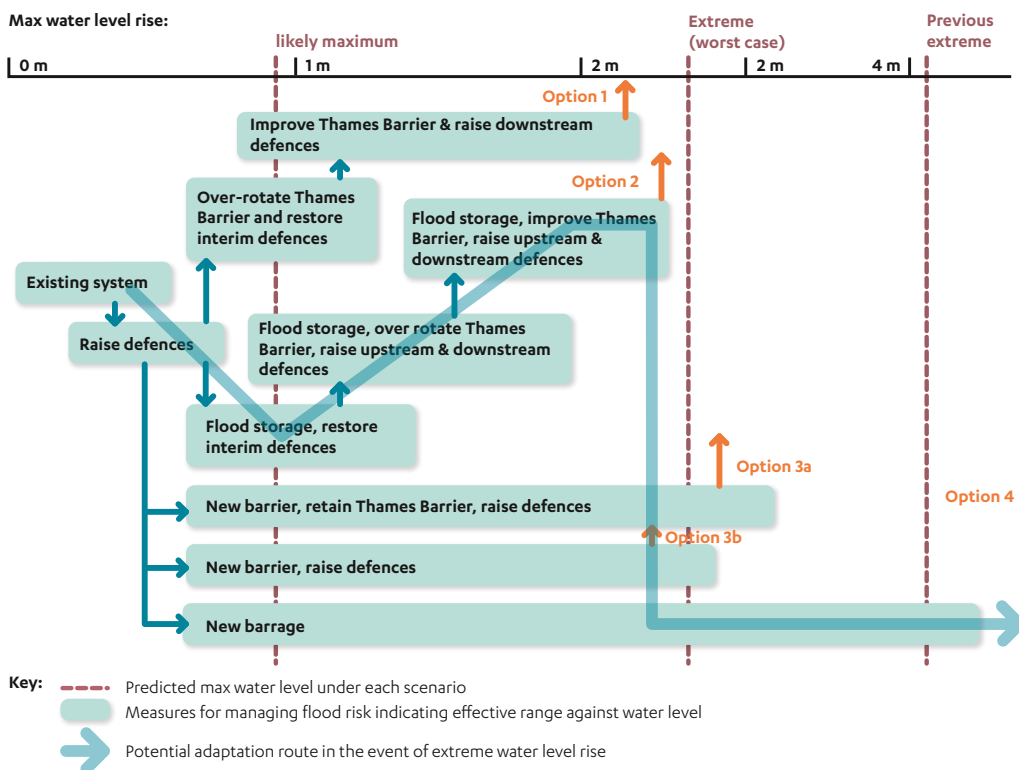
There is also a strong case for joining up between different interests at the level of individual water catchment areas. The Government has proposed an approach to management based on catchment areas which involves collaborative working in each of the catchment areas across England, of which there are about 80.²¹ More than 1,500 organisations are involved including the Government, water companies, non-government organisations, local authorities, landowners, farmers, angling clubs and universities. There has been some success in getting partners to share their data, but these partnerships have only achieved limited real change in management of infrastructure within catchment areas.

The Commission recognises that the number of different organisations makes coordination challenging, but changing responsibilities would create other difficulties. There is a clear need for coordination and joined up long-term planning. Catchment based working and regional groups provide examples of how the current system can be made to work.

There is still considerable uncertainty as to how aspects of climate change may develop. It is therefore important to consider infrastructure needs in different scenarios, and to put in place a framework for decisions that takes account of uncertainty and the lead time needed for planning and construction of infrastructure. This ‘managed adaptive’ approach uses different climate projections to allow uncertainty to be considered.

This approach has been used successfully in planning some major water and flood infrastructure, but it should be adopted more widely. A good example is the Thames Barrier scheme which has successfully defended London and the Thames Estuary from flooding since the early 1980s. The original design included some allowance for rising sea levels, but better protection is likely to be needed from the 2030s. Given the uncertainty in climate change over the century, the plan needs to be flexible. The Thames Estuary 2100 plan adopted a managed adaptive approach and Figure 6.2 shows four options and decision pathways to maintain protection. Research has been conducted to narrow uncertainties where possible. The plan enables different options and packages of measures to be tested against different social, economic and climate change scenarios, with a review about every 10 years (or earlier if suggested by monitoring). This approach is designed to provide flexibility to move from one option to another as the actual effects of climate change unfold.

Figure 6.2: High level options for flood risk management in the Thames Estuary in the next 100 years²²



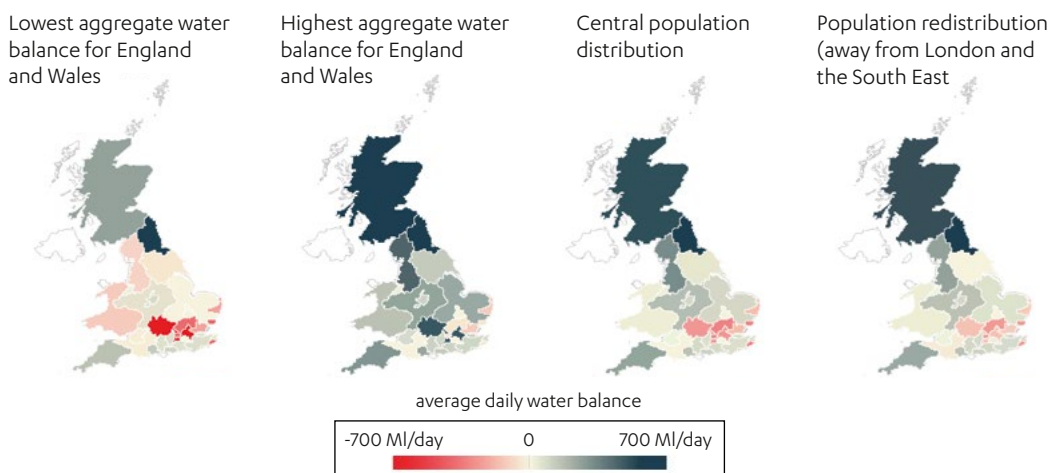
To ensure a full range of options are available it will be necessary to identify the land required for major new infrastructure projects and safeguard it from other development. The long timescales and wide range of options for some flood and water management projects may make this difficult. It will therefore be necessary to find a proportionate process for long-term safeguarding, to support implementation of managed adaptive approaches. Similarly it will be important to minimise future risk, for example by limiting development (including infrastructure) in the highest risk areas and ensuring appropriate resilience is incorporated from the outset.

Water supply

Policy already focuses on long-term planning for water supply, and Government and Ofwat (the water regulator) are together under a duty to secure long-term resilience.²³ Water companies are required to produce Water Resources Management Plans every 5 years, which must set out analysis of demand for water resources and options for meeting this over at least 25 years. Companies are currently preparing new plans for 2019.

Unless there is an increased response to the combined pressures of climate change and population growth, there is likely to be a significant risk of water shortages in the next 30 years. The Commission's modelling (shown in Figure 6.3 below) indicates that the South East of England will face particularly significant supply deficits by 2050. This picture of long-term shortages also emerges from analysis carried out as part of the water resources long-term planning framework, led by Water UK.²⁴ The South East faces particular challenges even in a scenario where London's population grows more slowly than currently projected, with the population redistributed to other parts of the country. However, in some scenarios which the Commission has modelled, water supply deficits would emerge elsewhere in the country too, including the North West and the West of England.

Figure 6.3: Water balance (million litres per day) for water companies across the UK in 2050



Footnote: Average daily water balance is calculated based on the annual difference between deployable output and distribution input. Further details on the Commission's modelling are available on the Commission's website.

Regional shortages are an important challenge even if there is more than enough water supply across the whole country. It is difficult to transfer water between areas and regions, although Ofwat has a strong focus on enabling trading.²⁵ Although there are a number of connections, the most severe droughts are likely to be widespread so water may not be available to transfer when it is most needed.

It is also important to consider users of water other than homes and offices. About 84% of total water taken out of natural systems in England is used by water companies for public water supply.²⁶ However water resource pressures in some regions will also affect industry, agriculture and energy generation, which are also permitted to take their own water directly from the environment.²⁷ It is important to ensure demand from these other users is taken into account and that the resources can be balanced across the different needs, including the natural environment. Different choices in energy supply – discussed in chapter 4 – will have different implications for water demand.

Waste water

Waste water infrastructure is also under growing pressure. New hard surfaces, such as roofs and drives in housing developments, will result in more water running off and needing to be drained. This will be increased further by more intense rainfall as a result of climate change. Population growth will mean greater volumes of sewage requiring treatment. Water companies have a less well-developed understanding of their waste water infrastructure than they do for water supply, undermining their ability to plan for future pressures.

The lack of long-term planning makes it difficult to effectively undertake maintenance, replacement or new infrastructure. It makes it harder to work collaboratively with wider stakeholders, for example on local flood risk management. Improvements are needed to understand risks from waste water infrastructure and requirements for additional capacity or infrastructure such as sustainable drainage systems. Data collection is likely to take significant time and effort and will itself need to be planned effectively.

Available information suggests that current maintenance and renewal rates for the sewer network will need to rise significantly if current standards are to be maintained in the long term. Current renewal rates for sewers are 0.2% per year giving an implied service life of 500 years.²⁸

Copenhagen's Climate Change Adaptation Plan

Following a series of severe rainfall years, together causing around £1 billion in damage, Copenhagen set out a comprehensive framework for addressing the risk in its Climate Change Adaptation Plan of 2011.²⁹ In preparation, Copenhagen commissioned detailed forecasting work on the future impact of climate change on the city, which predicted a 25-55% increase of rain in the winter.

In response, the plan sets out three levels of climate adaptation, based on the feasibility of implementing measures. Where the risk of damage is unacceptably high the first level of the plan is enacted. Measures include constructing dykes, expanding sewer capacity and directing storm water flows.

The second level, adopted where level one measures are not justified economically or not technically possible, includes watertight basements and adapting public spaces to store rainwater. Finally, for the lowest priority areas, the plan considers reactive measures like groundwater pumps and moving electrical cabinets from basements.

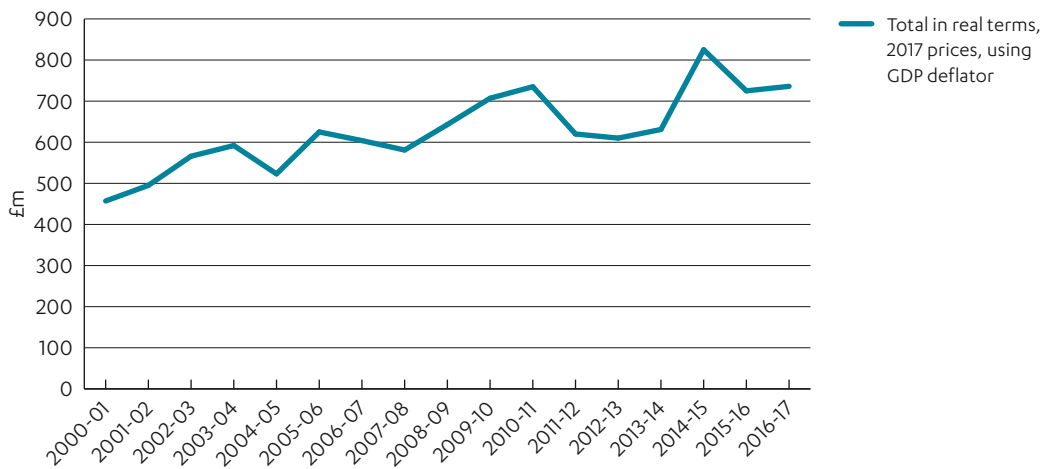
For rainwater generally, the plan sets a preference for sustainable drainage systems over sewer expansion, given the higher costs and disruption caused by the latter. The plan, together with specific work on rainfall, recognises the need to work across local authority boundaries to reflect water catchment areas.

Flood risk management

Historically flood risk management has been shaped by significant flooding incidents such as the east coast floods in 1953, which resulted in over 300 deaths. More recently widespread flooding in 2007, in which 13 people died, was followed by the Pitt Review with recommendations reflected in Government policy and legislation, particularly the Flood and Water Management Act 2010.³⁰

Some attempts have been made to consider long-term climate change and population pressures, for example the Foresight Future Flooding study for the Government Office for Science in 2004.³¹ The study led to a new Government strategy, but it wasn't until the 2007 floods and the Pitt Review that more substantial progress was made. Despite these long-term assessments, stop-start funding remained as shown in Figure 6.4.³²

Figure 6.4: Central Government funding for flood and coastal erosion risk management³³



The six year capital programme for 2015-2021 allows greater certainty and should result in more efficient planning. It will improve protection to 300,000 homes and reduce estimated risk by 5%. However, there is no clear long-term strategy for the level of flood protection that the Government is seeking to achieve, and how this will be met in the face of rising pressures. Without this, it is difficult to assess what the right level of spending in future periods should be.

The Flood Re scheme was launched in 2016 to provide affordable flood insurance for properties remaining at significant likelihood of flooding. Flood Re is planned to cease by 2039 and enable a transition before then to market-based insurance fully reflecting flood risk. However the current transition plan focuses on improving understanding rather than tangible action to reduce risk, for example by requiring resilience repairs following flooding.³⁴

Analysis commissioned by the Committee on Climate Change for its 2017 Climate Change Risk Assessment suggests flood risk will increase by at least 50% by the 2080s if no further action is taken.³⁵ This does not take into account future population growth, which further increases the risk. Further analysis of infrastructure at risk was undertaken for the National Flood Resilience Review, but this only considered river and coastal risks and interdependencies or cascade failures are still not well understood.³⁶ Some aspects of flood risk, such as surface water, are also not well understood. Government committed to further work to consider surface water flooding in 2017 and recent research by the Met Office suggests that there is a high risk of unprecedented rainfall occurring.³⁷

Hierarchy of flood and coastal erosion risk management approaches

The risk of floods and coastal erosion can never be entirely prevented, but a range of approaches can be used, often in combination, to manage the risk. Risk is defined in the Flood and Water Management Act 2010 as a combination of the probability of an occurrence with its potential consequences. The Act goes on to define risk management as including the analysis, assessment, reduction or alteration of the balance of factors for a risk. A list of examples is provided, but in addition to assessment and analysis (understanding the risk by collecting data, analysing, mapping etc) there are three general approaches:

Protection: typically reduces the probability of flooding or erosion at a community scale and takes place through traditional defences (such as flood walls) or catchment management to reduce flows. This can include the use of powers to ensure or prevent changes to the flood risk system and maintenance / operation of assets.

Adaptation: action to reduce the consequences of flooding includes property level resilience (e.g. flood gates or waterproofing individual properties) or relocating assets away from the risk of flooding.

Response and transfer: responding to flood events including forecasting and warning, incident management and coordination, recovery (reinstatement of damage). Insurance can be used to transfer the risk.

Typically protection is preferred and the benefits of works often outweigh costs by a substantial amount (the National Audit Office reported that the ratio of benefits to costs across all projects in the flood risk management capital investment programme as of March 2014 was estimated to be 9.5:1).³⁸ Adaptation can also have significant benefits, but is typically less efficient and less desirable for communities so is generally only undertaken where protection is not feasible. Response and transfer often supplement other forms of risk management. Costs will reflect the level of risk that remains after protection / adaptation. While insurance can help individuals cope with the risk they face (by averaging over time / location) it does not actually reduce the risk.

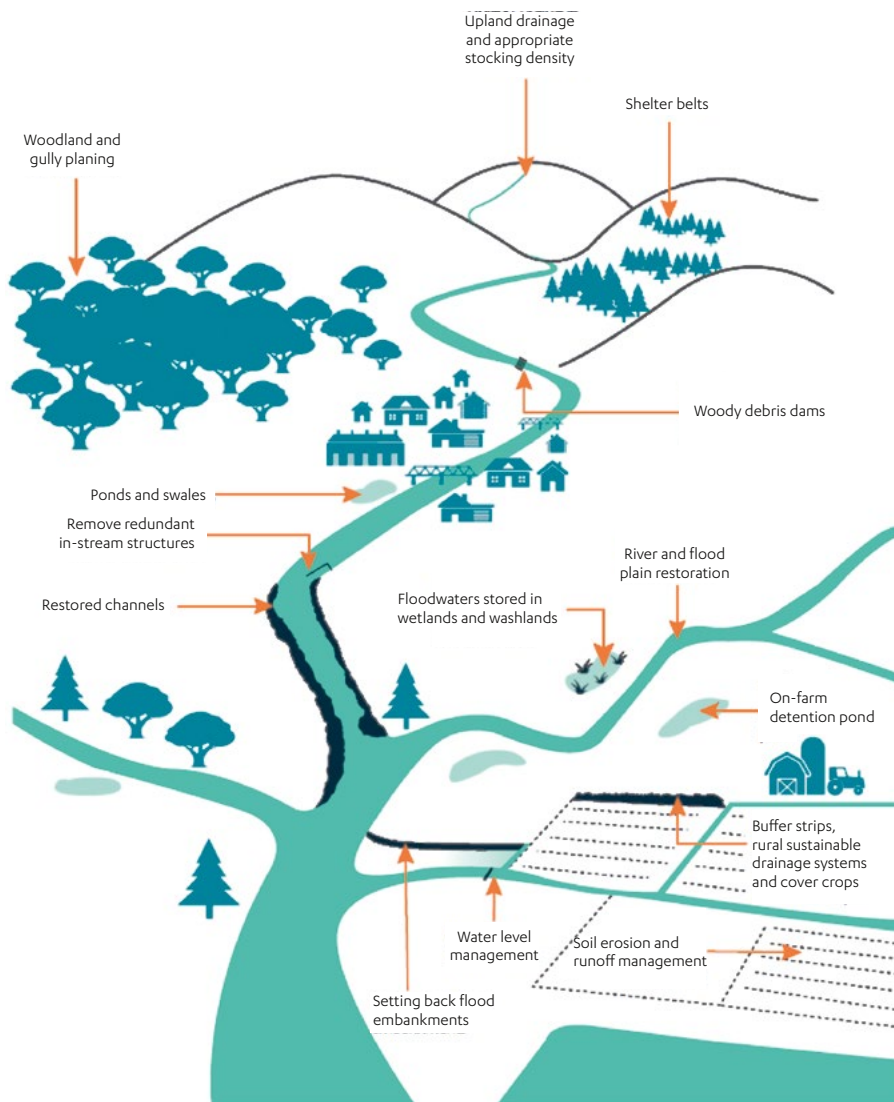
‘Green infrastructure’ can play an important role in flood risk management and also help recharge groundwater and improve water quality. It often involves managing water across the wider catchment area, rather than just where flooding occurs or pollution becomes a problem, through modification of land use, land management and active management of upstream river channels and floodplains.³⁹ However, whilst these approaches deliver wider benefits (including to the environment and quality of life) the delivery of ‘natural’ flood management is often less certain and less reliable in severe events. A more open and strategic approach that ensures the full range of options are considered at the outset of project development is needed rather than setting aside separate funding for environmental or natural projects.

Green infrastructure

Green infrastructure refers to environmental features, often managed, that also provide infrastructure services. Some of the best examples of green infrastructure are in flood and water management. Catchment management and urban runoff management through sustainable drainage systems are often used to reduce the risks of flooding, but can also deliver wider benefits such as recharging groundwater and improving water quality.

There is increasing use of approaches to manage water across the whole catchment, rather than at the point at which flooding occurs or pollution becomes a problem, through modification of land use, land management and upstream river channels and floodplains. Figure 6.5 illustrates interventions across the catchment which, as well as mitigating flood risk, can deliver wider benefits such as remediation of pollution, mitigation of soil erosion, habitat restoration and carbon storage.

Figure 6.5: Flood management interventions across a catchment⁴⁰



The Commission's priorities

The Commission believes that the challenges set out above can be overcome. Water and flood management infrastructure should better reflect public expectations, despite the pressures, but action is needed now.

Technology

Although many aspects of water and flood management use long established approaches, technology is already widely used, for example in sensors, modelling and automating water treatment. New technologies allow for more active management of water pressure within the network, which can be used to reduce leakage. Better real-time data from sensors, in-pipe cameras or drones could help target maintenance, reducing both costs and interruption in services for customers. There are considerable opportunities for more innovation to deliver incremental improvements for new developments and through new materials or processes such as membrane technology.

Smart water meters have the potential to provide hourly data, instead of just two or so readings a year for conventional meters. This allows leaks within individual properties to be identified and addressed. It should also allow householders to be more aware of their use of water: the introduction of compulsory meters by Southern Water reduced consumption by more than 15%.⁴¹ Smart meters could also enable variable tariffs, with prices adjusted to reflect how much water is being used or to respond to times of shortage. However there appears to be little support for these within the industry or public at present.

Companies are also increasingly using meters and other sensors to better understand their networks as well as measuring water delivered to customers. Measuring water pressure and chemical content as well as flow allows the supply networks to be run more effectively and adjusted in response to changes as they happen. Monitoring water discharged from the network and the condition of water environments may also allow treatment of waste water to be improved.

Machine learning allows computers to use data to build a picture of how a network operates without needing a detailed understanding of all of the different components. It could be particularly useful for understanding how to reduce water leakage and energy consumption.

Sensors built into infrastructure can be complemented by remote sensing, such as increased use of drones to gather information on the extent of flooding, the condition of infrastructure or the location of water leaks. This should allow better response to incidents and, if combined with a detailed analysis of failures, a better understanding of how maintenance or asset replacement can be targeted to improve service.

For individual households, greater adoption of water-efficient fittings could play an important role in reducing demand for water, waste water and water heating. The reductions this could deliver on water and energy bills provide incentives,

although improvements in standards have often been driven by regulation. For example, the Greater London Authority has adopted a ‘fittings-based’ approach for new developments, providing maximum water consumption values.⁴² Industry research suggests there are an estimated 1 million toilets flushing on more than 13 litres of water, more than three times the amount used by higher efficiency dual flush toilets.⁴³

Technology is likely to allow a better understanding of complex risks such as surface water flooding, which require a high level of detail for meaningful modelling or assessments. Similarly improved data on rainfall, water and sea levels can be used to enhance forecasts and warnings. These can be communicated better and in a more targeted way to the public and responders using the latest communications technology.

The Commission’s New Technology Study will include work on water supply and maintenance over the coming months.

Funding

Funding for flood and water management activities generally reflects organisational responsibilities. Water supply and waste water services are paid for by water company customers. Most funding for flood and coastal erosion works is provided by the Government from taxation, whether directly through grants or indirectly through public sector contributions as part of ‘partnership funding’. There is also use of EU funding for flood management in some areas, and a levy on household insurance enables subsidised cover in high flood risk areas through the Flood Re scheme.

These different sources of funding have different timescales and requirements. Stakeholders have identified problems with combining funding from different sources or for different objectives, to deliver projects addressing more than one challenge.

Water companies have delivered large capital investment programmes to improve waste water treatment over recent years, mainly driven by EU requirements. There has not been equivalent investment in improving resilience to drought. The UK’s exit from the EU may provide an opportunity to look across the various objectives for further investment and identify the best balance of priorities for each regulatory period.

Encouraging greater investment in underground water networks could help to reduce leakage and pollution. Increasing water efficiency could free up funding for investment without increasing bills for customers. The Government has announced that the regulatory and support regime that replaces the EU Common Agriculture Policy should put ‘environment protection and enhancement first’.⁴⁴ Such a system could be designed to encourage landowners to set aside land for natural flood management, or to reduce flows of pollutants that contribute to demand for treatment plants into rivers and lakes.

The capital programme for flood and coastal erosion risk management was set for a six year period from 2015-21, and funding for maintenance has also been committed to 2021, but other resource funding is confirmed on an annual basis. In contrast, water company investment is assessed on a 'total expenditure' basis and set through price reviews on a five year cycle, with the current Asset Management Period running from 2015-20.

The six year capital programme allows flood risk management authorities to plan work with greater certainty. Extending the infrastructure programme (including maintenance), for example to a rolling six year period, should deliver greater efficiencies. Similarly, more consistent requirements for different approvals and timescales of jointly funded projects could enable more partnership working.

Surface water flooding, where heavy rainfall overwhelms drainage networks, is a significant risk. The Environment Agency assessment suggests that overall there are more properties at risk from surface water than other sources of flooding.⁴⁵ Lead Local Flood Authorities (county councils or unitary authorities) are responsible for developing local flood risk management strategies in their areas. However, local authority budgets are under increasing pressure and more detailed understanding of risks and investment, including sewer capacity, is needed. This is likely to require concerted action by all flood risk management authorities including water companies.

Insurance is a key part of flood risk management, allowing individuals to pool risks over time and across different areas. It does not itself reduce the risk, but can incentivise risk reduction. The Flood Re scheme is funded through a levy, currently £180 million a year, on household insurance and currently uses this to subsidise flood cover for about 130,000 households although it estimates this could rise to 350,000.⁴⁶

Making it happen

Preparations for the 2019 price review process for water companies are already well underway, and will set the programme for their investment between 2020 and 2025. Analysis carried out by the industry-led 'water resources long-term planning framework' considered a range of water supply and demand options.⁴⁷ It concluded a 'twin-track' approach would be needed comprising demand measures such as reducing leakage and household water use and supply measures such as building new reservoirs or connections for water transfer.

It will be important that this process considers all options, including those that require different water companies to work together, and that the Government, Environment Agency, Ofwat and the industry take responsibility for effective delivery.

The approach to leakage reduction set by Ofwat has guided companies to aim for a 'sustainable economic level of leakage'. This sought to reduce leakage up to the point at which it is no longer cost effective to go further, relative to other options such as collecting more water from the environment. New technology should

increase the scope for reducing leakage at any economic level. It is also important to ensure that the full range of costs and benefits are captured in appraisal of investment options. This includes taking account of the true costs of failing to address leakage including environmental impacts, taking a sufficiently long-term view, and considering public acceptability. Ofwat has proposed more stretching targets for the 2019 price review.⁴⁸ The Commission's social research aligns with views expressed by many stakeholders that leakage is considered wasteful and unacceptable by the public. Failing to address leakage risks undermining support for metering and other behavioural changes.

'Universal metering across the country is absolutely essential to addressing the supply-demand deficit.'

WWF call for evidence response

The Commission considers it important that water companies be bold and ambitious in their plans to make better use of existing infrastructure. Technology (such as smart meters) already exists which can help significantly reduce consumption and leakage. The Government and regulators must hold water companies to account and ensure opportunities are not missed, and any barriers are overcome.

Nonetheless some major new water supply infrastructure is likely to be needed well within the next 30 years. Various options are available, such as inter-regional transfers, new storage options such as reservoirs, or water re-use. Each has pros and cons and some combination may be the best solution. The Government has work underway to bring forward a National Policy Statement for water supply under the Planning Act 2008 (there is already one for waste water). This is timely and should set out the need for nationally significant water supply infrastructure, ensuring that all nationally strategic infrastructure, including transfers, are within scope.

The immediate focus for waste water is likely to be improving understanding and developing more robust long-term planning. Industry has initiated the '21st Century Drainage' programme led by Water UK, to develop a more coherent and strategic approach. The Commission welcomes this positive step. However swift progress must be made to gain a much better understanding of the challenges and to ensure that this leads to systematic long-term plans of action. This should include identifying and addressing the most urgent problems during the 2019 price review period (2020-25) as well as longer-term action.

Potential new water supply infrastructure

Inter-regional transfers

Transferring water through pipes or watercourses from regions with abundant water to more pressured regions at times of need. For example, Water UK's study suggests strategic transfers from Severn Trent to the Thames and Anglian regions will be needed.

- **Pros:** Provides flexibility to move water when needed. This may be a practical and cost-effective option in some water regions compared to collecting more water within the region.
- **Cons:** Water is heavy, and so expensive and energy-intensive to pump – although this is potentially less of an issue if transfer is used only as a back-up. There are significant commercial and technical barriers to overcome. Droughts may hit multiple regions simultaneously and there could be environmental impacts, for example varying chemical properties and invasive species.

Reservoirs and storage

Surface water storage options such as reservoirs, and groundwater development such as storage in underground aquifers.

- **Pros:** Reduces need to increase collection from local water sources, and likely to be less complex from a logistical and commercial perspective than transfers. Reservoirs can also be used to store transferred water. There is some scope to share water with other users.
- **Cons:** Fixed location and long delivery timescales means there is a risk of assets becoming obsolete. In densely populated areas such as South East England, the large space requirement poses a challenge to building local support and getting planning consent.

Water re-use

Treatment and transfer of wastewater, either to watercourses used for water supply or potentially directly into the water supply.

- **Pros:** Reduces need to collect water from natural systems, and can provide a reliable and plentiful boost to local and regional supply during periods of drought. This can also help maintain river flows, with potential environmental benefits. This can be used when needed.
- **Cons:** In addition to building costs, it is expensive and energy-intensive to pump and treat wastewater for re-use. There are also social acceptability concerns, particularly if direct re-use were to be considered.

Desalination

Treatment of salt water to make it fit for use in the public water supply.

- **Pros:** Relatively quick and cheap to build, typically as a back-up option for use during a drought.
- **Cons:** Expensive and energy-intensive to operate, although potentially less of an issue if used as a back-up. Environmental concerns with disposal of sea salt by-product.

In the longer term it is important to review how far the regulatory approach for water companies delivers innovation and collaboration between water companies. Innovation is a particular focus in Ofwat's draft methodology for the 2019 Price Review.⁴⁹ It will also be essential to ensure that investment levels are fair to future as well as current customers, as ducking difficult decisions now will leave future generations to pick up the tab.

The Commission will consider how Government and the industry can take a longer-term perspective on flooding, drainage and sewerage to stay ahead of rising risks. This will form part of the next stage of analysis for the National Infrastructure Assessment and will allow consideration of whether the level of ambition in flood risk management is appropriate. The Government's response to the Environment Food and Rural Affairs Parliamentary committee report '*Future Flood Prevention*' noted that the 'Environment Agency is due to refresh the national strategy' but didn't set out a timescale.⁵⁰ This provides a good opportunity to set out a long-term strategic approach alongside investment and funding options. It should reflect an honest discussion with the public about the level of risk and constraints on protection.

The Government is also committed to producing a 25 Year Environment Plan and is receiving advice from the Natural Capital committee as well as undertaking pioneer projects to identify good practice and innovative solutions. National and local strategies should consider the full range of options. Green infrastructure and other measures should be considered on a fair basis with traditional infrastructure approaches to maximise the benefits that can be achieved.

The Commission's vision for the future

Meeting the Commission's vision would see the UK have:

- resilience to the rising risks of drought and flood. That means doing more than simply running to stand still.
- much lower levels of leakage and waste, underpinned by use of new technology such as smart meters.
- infrastructure that contributes to a thriving environment.
- joined-up and strategic long-term planning, both within and across flood and water management systems.

Questions for consultation

Given increasing pressures from climate change and population growth, and the need to safeguard the environment, it will be necessary to make better use of the water that is available. Metering can help identify leaks and encourage customers to use less water but will not be enough by itself.

- 23) What should be done to reduce the demand for water and how quickly can this have effect?**

Reducing demand is unlikely to be enough to secure resilient water supplies. Some major new water supply infrastructure is likely to be needed well within the next 30 years.

- 24) What are the key factors that should be considered in taking decisions on new water supply infrastructure?**

There is limited understanding of current drainage and sewerage capacity. Although pressures are increasing, there is little long term planning.

- 25) How can long-term plans for drainage and sewerage be put in place and what other priorities should be considered?**

Flood risk is increasing due to climate change and population growth. A range of actions are already being taken to manage risk, but the overall level of ambition is unclear.

- 26) What investment is needed to manage flood risk effectively over the next 10 to 30 years?**

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- ¹⁵ National Infrastructure Commission calculations based on: Environment Agency (2015) **Water supply and resilience and infrastructure: Environment Agency advice to Defra** and Environment Agency (2016), **Managing flood and coastal erosion risks in England 1 April 2015 to 31 March 2016**. Risk calculated as 1% annual likelihood.
- ¹⁶ For example **Thames Water Trunk Mains Forensic Review** found 18 of the 30 bursts from 2016 were on mains over 100 years old (with the oldest dating from the 1850s) but concluded “whilst the date of installation influences the likelihood of failure, it may not be the predominant factor”
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- ¹⁹ Chartered Institution of Water and Environmental Management (2011), **Policy Position Statement: New public water supply reservoirs**
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⁴⁶ FloodRe (2017), **Annual Report**. The scheme excludes any properties built after 2009 to guard against moral hazard, but also commercial properties and most residential leasehold properties.

⁴⁷ Water UK (2015), **Water resources long term planning framework**

⁴⁸ Ofwat (2017) **Delivering Water 2020: Consulting on our methodology for the 2019 price review** proposed that companies justify leakage against options including a 15% reduction by 2025 or upper quartile performance

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7. FINANCING AND FUNDING INFRASTRUCTURE IN EFFICIENT WAYS

The need for action

Infrastructure typically requires large up-front investment, followed by a long period of lower maintenance and operational costs. Finance – raising capital from external sources – allows the cost to be spread over a long period. It can play an important role in meeting the country’s infrastructure needs in a timely manner and addressing the challenges set out in this report. Finance should be differentiated from ‘funding’ which refers to the way in which the costs (including those for financing) are ultimately met.

Finance itself is not in short supply. The Commission has found that projects can generally be privately financed if an adequate funding stream is available.¹ Very often when a project does not appear to have sufficient access to finance, the underlying problem is that it lacks a credible source of funding. A number of different funding structures are discussed elsewhere in this document including road pricing (in chapter 5), land value capture (in chapter 2) and city region transport funding (in chapter 2).

Substantial parts of the UK’s infrastructure, including most of digital, water and energy as well as significant elements of transport and waste management, are owned by the private sector and funded by households and firms through their bills. These are almost entirely privately financed.

However, there may still be a role for Government. Even when investors are satisfied there is an underlying funding stream, some risks require Government support to ensure financing can be secured. For example, where demand is uncertain or dependent on delivery by others, especially by the Government itself, then the Government or regulators can link payment to availability of an asset, rather than use. This can create a funding stream that is sufficiently reliable to make a project financeable.

Government assistance may also be needed to provide insurance against extreme or very hard to calculate risks, where this is too difficult for the investors alone (due to the scale or nature of the project). In some cases, extremely large projects may be too large to be supported by the balance sheet of the relevant contractors. A long-term Government commitment may be needed to secure the patient and sustainable capital that is often needed for infrastructure development.

Other networks, including road and rail, flood risk management and significant elements of waste management are owned by the public sector and funded by taxes, fees or charges. There is also some public funding in areas such as rural broadband and energy efficiency. In many cases, projects that are publicly funded are also publicly financed: the public sector raises the upfront costs either through taxation or generic Government borrowing (as opposed to financing specific projects).

However, where public expenditure is constrained, the use of private finance can allow projects to go forward that might otherwise be delayed. The UK has established a track record in making the most of private finance, through its pioneering use of mechanisms such as public private partnerships. These approaches

transferred some risks associated with delivering projects to the private sector and benefitted from private sector efficiencies, whilst using public funding to pay for projects over time.

The private sector can provide expertise and financial discipline in addition to financial resources. Where effectively deployed, this can improve the efficiency of infrastructure services. Competition in an open market, competition for Government contracts, and auctions for taxpayer support have been used to drive down costs, stimulate innovation and improve quality. The Competition and Markets Authority estimated that the use of competitive auctions in the energy sector has reduced the need for public support by 25%.²

The development and use of new private financing approaches appear to have slowed in recent years. A number of factors may explain this, including constraint in public funding, the absence of an adequate alternative revenue stream such as tolls (which are used in many other countries) to repay investment, and the fact that the capital costs of these projects are now more likely than in the past to be classified as public spending even if finance comes from a private investor. Some privately financed projects also suffered from high ongoing costs or inflexibility when service levels changed. The lack of a clear methodology for value for money comparisons between public and privately financed alternatives has also contributed to uncertainty about the benefits of private finance. However, the Government's July 2017 Transport Investment Strategy sets out a renewed focus on alternative sources of funding (particularly from beneficiaries) and private finance.³

Where the public and private sector work in partnership, it is clear that interests must be balanced. Private investors will seek stable returns and a manageable risk burden, and the public sector will want to achieve good value for money, a meaningful transfer of risk to investors and a fair deal for users. However, a lack of consistent evaluation of past projects makes it difficult to draw reliable conclusions on the whole life costs of comparable, publicly funded projects using private finance, compared to those wholly financed within the public sector.

The Commission's fiscal remit

The Commission's recommendations must fit within a 'fiscal remit' set by the Government.⁴ This sets a limit on the public expenditure available where Commission recommendations have public expenditure implications.

On 23 November 2016, the Government published the remit for the Commission. This states:

"The [Commission] 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 1.0% and 1.2% of GDP in each year between 2020 and 2050. This remit applies to both the National Infrastructure Assessment and future specific studies. The [Commission] should clearly prioritise their recommendations

and explain which they consider are most critical in addressing the country's long-term infrastructure needs."

The Commission's fiscal remit provides the boundaries within which hard choices about infrastructure priorities must be made. The remit covers capital expenditure by the public sector on both upgrades and maintenance. It does not include day-to-day ('resource') costs nor spending by devolved administrations. The remit relates to total investment spending so is not affected by recommendations regarding income from taxes, tolls and fees.⁵ The remit specifies that the Commission should use Office for Budget Responsibility forecasts for GDP.

Capital expenditure falls within the remit if the body responsible for the expenditure is classified to the public sector by the Office for National Statistics, according to National Accounts definitions. The definitions are complex but relate ultimately to an assessment of who bears the risk and rewards associated with the asset in question. Activity may score to the public sector even if it is privately financed (for example some projects under the Private Finance Initiative are now classified to the public sector) or undertaken by organisations which are not owned by the Government.

Table 7.1 below sets out the Commission's preliminary estimate of existing spending within the definition of the fiscal remit. No single data source is available to match this definition. The Office for National Statistics published estimates of infrastructure expenditure in July 2017.⁶ They estimate that Government investment in infrastructure in 2015 was £16.2 billion (0.9% of GDP). However, this measure does not match the definition of the fiscal remit, in particular:

- It includes spending by the devolved administrations in Scotland, Wales and Northern Ireland, which is excluded from the fiscal remit;
- It excludes spending by public corporations, such as London Underground, which is included in the fiscal remit.

The Commission has therefore constructed its own estimate, using a range of published data:

- Data for transport comes from the online system for central accounting and reporting database underlying *Public Expenditure Statistical Analyses*, using the United Nations Classification of Functions of Government definitions.⁷ Network Rail expenditure, which was classified onto the Government's balance sheet in 2014, has been backdated using Network Rail's own accounts.⁸
- Data for local Government spending on solid waste management also comes from the database underlying *Public Expenditure Statistical Analyses*.
- Data for flood risk management comprises capital expenditure on flood risk management from the Department for Environment, Food and Rural Affairs, together with an estimate of 'partnership' funding

from local authorities from the Department for Communities and Local Government's *Local Authority Capital Estimates Return*.⁹

- Data for digital comprises Broadband UK capital expenditure from the Department for Digital, Culture, Media and Sport.¹⁰
- Data for energy comprises capital expenditure on energy efficiency programmes (the Green Deal Home Improvement Fund and the Green Deal Communities) from the database underlying *Public Expenditure Statistical Analyses*.¹¹
- The Commission is unaware of any spending on the water sector that would score within the fiscal remit.

Table 7.1 Commission estimate of spending within the fiscal remit, 2012/13 to 2016/17

£m	2012/13	2013/14	2014/15	2015/16	2016/17
Transport					
<i>national roads</i>	£1,020	£1,370	£1,890	£1,950	£2,090
<i>local roads</i>	£2,370	£2,680	£3,330	£3,450	£3,450
<i>local public transport</i>	£290	£200	£220	£250	£240
<i>railway</i>	£7,950	£9,830	£9,510	£10,220	£10,820
<i>other transport</i>	£100	£280	£380	£690	£1,090
Transport (total)	£11,720	£14,370	£15,330	£16,560	£17,700
Waste Management	£350	£410	£450	£450	£430
Flood Risk Management	£270	£330	£440	£400	£480
Digital	£10	£60	£230	£210	£50
Energy	£0	£5	£110	£60	£0
Water	£0	£0	£0	£0	£0
Total	£12,360	£15,160	£16,550	£17,690	£18,660
<i>(as a % of GDP)</i>	<i>0.73%</i>	<i>0.86%</i>	<i>0.90%</i>	<i>0.94%</i>	<i>0.95%</i>

Substantial parts of the UK's infrastructure are in the private sector, including most of the water, energy and digital sectors as well as some parts of the transport (eg ports and airports) and solid waste sectors. Commission recommendations in these areas will not, for the most part, impact on the fiscal remit. They will however affect the bills that households and businesses have to pay. Those bills affect the UK's competitiveness and people's quality of life, so any additional costs need to be balanced against the benefits they bring.

Reflecting this, the Commission's remit also requires the Commission to provide "a transparent assessment of the costs to businesses, consumers, Government, public bodies and other end users of infrastructure that would arise from implementing the Commission's recommendations."¹²

How things stand

Where projects are in the private sector, the cost of financing can have a significant impact on household and business' bills. For example, Ofwat guidance to water companies states that a 0.5% increase in the cost of borrowing for investment increases annual bills by around £10 (compared to average water and sewerage bills of £395 per household).¹³

In most cases, private financing of infrastructure works well. However, there are a number of options available to Government to help support private infrastructure finance where necessary, by ensuring a secure funding stream or providing a balanced distribution of risk. Infrastructure development nearly always has some element of public benefit, as well as the private benefits to utility companies and their customers. For example, investment in water and wastewater infrastructure has environmental and health benefits, as well as benefits to customers. This may justify a degree of Government support for projects that are in the private sector. Options include:

- *Funding through regulated utility structures.* Regulators can allow utility companies to pass the costs of investments through to customers, creating a near-guaranteed funding stream for projects which might otherwise be too risky. Regulators normally review the returns that utility companies can make every 5-8 years, but longer term arrangements exist, such as those used by the regulator for gas and electricity markets (Ofgem) to develop a regulatory regime for new offshore transmission assets.
- *Pre-funding during construction.* One challenge for major projects is that there can be a considerable delay – many years – before projects generate revenues, because of the time taken for construction. Investors, in contrast, often prefer an immediate return, to match cash flows such as pension payments. Regulators can allow for pre-funding to address this gap. In the case of Thames Tideway Tunnel, the regulatory regime enables Thames Water to charge customers for the benefits of the project, before they are realised, during its construction phase.¹⁴
- *Addressing risks relating to payment or public sector delivery.* Contracts can be provided on an 'availability' basis, where payments are made once the new infrastructure is made available for use. The trains being provided by the Intercity Express Programme were purchased on this basis. This means that private investors take all the risks associated with building the trains, but aren't expected to bear any of the public sector delivery risks such as whether necessary improvements to track are completed on time.¹⁵
- *Addressing risks that can't be insured.* The Government can commit public sector cover for large uninsurable risks or uncertain demand in very large projects. As part of the Thames Tideway Tunnel project,

Government support covers specific low probability, high impact risks associated with digging under London.

- *Underpinning the funding of local government.* The Government has given guarantees on the ability of local authorities to repay borrowing for specific projects, where their own resources may be too small for lenders to have sufficient certainty on this – for instance on the Mersey Gateway bridge. Devolution of greater responsibility for funding infrastructure to local and regional bodies may necessitate more support of this type.

Mersey Gateway

The Mersey Gateway is a new toll bridge crossing the River Mersey, currently being delivered by Halton Borough Council. The total project cost is £1.86 billion.

A number of Government interventions allowed the project to go ahead, with regular availability and annual payments to the operator providing the majority of the funding. A capital grant of £86 million reduced the up-front financing requirement. A Government guarantee under the UK Guarantee Scheme provided investors with greater confidence. This was worth the equivalent of £14.5 million annual support, and improved the financial viability of the project.

Without the guarantee and the capital grant, the local authority would not have been able to go ahead with such a large project.

Government support for projects can also help to mitigate risks that Government itself creates. Policy risk can be significant in infrastructure service delivery, since Government often plays a substantial role in these markets even if there is no direct public sector provision. Where the Government has ‘skin in the game’, it will be more costly to reverse or disrupt long-term strategic investment policy or decisions. This could lead to better decision making and greater consistency by Government.¹⁶

The future role of key investment institutions is uncertain

Alongside private investors, the European Investment Bank and Green Investment Bank have been significant investors in UK infrastructure. The European Investment Bank invested £35 billion in UK infrastructure between 2011 and 2015, as part of its function in providing cheap finance and acting as a centre of excellence in engineering and project analysis. In 2015 it invested €7.8 billion in the UK.¹⁷ This investment is generally provided at cheaper rates than could be obtained by infrastructure operators from other sources of finance.

Their role also includes mobilising other private investment by providing confidence to other lenders. Many investors may not have the expertise or appetite to conduct their own analysis for investment in new and ‘risky’ technologies or projects. Investment by an institution such as the European Investment Bank can send a positive signal to these investors about the commercial viability of a project. For

example, it played a significant role in providing finance to Offshore Transmission Owners in the UK. Similarly, the Green Investment Bank has sought to ‘crowd-in’ other investors’ money by demonstrating how commercial returns can be made from financing greener infrastructure and projects.¹⁸

Offshore Transmission Owners

The offshore transmission programme involves new infrastructure for offshore energy transmission being competitively tendered – with winning bidders owning the right to operate and maintain the offshore infrastructure assets for a period of 20 years. These assets encompass the infrastructure used to connect offshore wind farms to the mainland (i.e. cables, pipes and substations).

Previously developers were responsible for consenting, licensing, constructing and maintaining all of the assets, from the turbines to the onshore substation. However, it was argued that this system was not cost-effective for this scale of development. A competitive tender process for the new infrastructure means that new offshore renewable generation projects are connected economically and efficiently. This should result in lower costs and higher standards of service for generators and ultimately consumers. The asset-based regulatory regime helps to protect the asset owners from the risk that the infrastructure they own could become outdated or economically unviable, by guaranteeing them a fixed revenue over a period of 20 years.

Analysis has found that the recent tendering process helped to save hundreds of millions of pounds in comparison to the main alternative approach, which is to incorporate offshore transmission assets into the ownership of onshore transmission companies and regulate it as part of the electricity price control framework.

The UK’s decision to leave the European Union makes the future of financing through the European Investment Bank uncertain. Without it, the cost of finance for relevant projects would be higher than it would otherwise have been.¹⁹ There may be further implications for levels of investment in infrastructure in new and ‘risky’ sectors.

‘The EIB is currently the largest single lender to the UK water industry, with over £6.5 billion borrowed by the ten water and sewerage companies in England and Wales over the period 2005-2016.

‘At this point it is unclear whether the EIB will be able to maintain its role as a provider of finance to the UK water industry following the UK’s withdrawal from the EU; if it does not, then other things being equal, costs to customers will be higher’

Water UK, call for evidence response

The Green Investment Bank helps to create new markets by offering to co-invest at an early stage in innovative but potentially risky technologies, in order to mobilise private investment. It has played an active role in a number of sectors, including renewable energy and waste treatment, investing £2.7 billion since it was established. The total value of the transactions it supported was £11.1 billion.²⁰

The privatisation of the Green Investment Bank brings into question its catalytic role in new technologies and sectors.²¹ As a private institution, concerns have been raised that it may gravitate towards more established sectors with a track record of stronger returns.²²

There may be more opportunities for private finance in the public sector

The use of private finance can allow public sector projects to go forward more quickly where there is a significant constraint on public spending. Public sector financing of the project may not be a viable option in the near-term. Private financing, spreading the cost to Government over time, may be the only way a project can be delivered in the short-term. Private sector disciplines can mean projects are delivered more efficiently and at lower cost, and that maintenance is properly managed over the lifetime of an asset.

Currently there is no widely used assessment of the cost of projects over their whole life that would allow an evidence-based comparison of different models. There may be too much focus on some elements of the costs and benefits of private sector involvement, such as easily measured borrowing costs, but insufficient account of real, but harder to measure, effects, such as operation and maintenance costs. It is important to compare over the long-term, since some key long-term costs such as maintenance or contract variations may differ systematically between models.

Similarly better data on the condition of infrastructure operated by public bodies could help improve understanding of the value that is added by private sector involvement. The discipline of developing projects for private sector involvement could sharpen incentives for the public sector to improve data on its assets, as this will be key to ensuring investors can properly price the risk they will bear.

Goethals Bridge and Silvertown Tunnel

The cost for the Goethals Bridge replacement project in New York and New Jersey is around \$1.5 billion. The project will be designed, built, financed and maintained by a privately owned developer, NYNJ Link. It is being financed by around \$450 million in Private Activity Bonds, issued by the New Jersey Economic Development Authority on behalf of NYNJ Link. The bonds are supported by a \$474 million loan from the US Department of Transportation and \$107 million of direct investment (equity) from the developer.

The Port Authority of New York and New Jersey will make payments to the developer at construction milestones and as completion nears. Following this the developer will receive regular fixed payments over a 35 year operating period, as long as it meets performance standards. The public sector will receive toll charges from users of the bridge which it can use to cover the regular payments to the developer, but since the repayments are fixed the public sector is bearing the risk that revenue raised from tolls will not match these payments.

In London, the £1 billion Silvertown Tunnel project has adopted a similar approach. Transport for London are seeking to appoint a private sector operator to similarly design, build, finance and maintain the tunnel in return for availability payments for a 25 year period. Whilst these payments will be dependent on the tunnel being safe for traffic use, they are guaranteed at a fixed rate regardless of the revenue raised from charging users. This removes a major risk for investors. As with the Goethals Bridge project, user charging income can be used by Transport for London to offset the availability payments to the private sector.

In both projects, the public sector helped balance risk sharing with respect to future demand – in exchange for transferring significant design and construction risk, as well as responsibility for user service and maintenance, to the private sector.

There are approaches used in other countries that the Government may want to emulate

‘Capital recycling’ is an approach used in some international comparators. Projects where there is a reliance on new or innovative technology, or where there is uncertain demand, may not be efficiently financed by the private sector. In these cases, the Government could meet the up-front investment costs and take the risks, with a view to selling the infrastructure to private owners. This could either be after the riskiest initial phase or once the whole project is complete and the infrastructure is in operation. The resources used for investment can then be recycled.

In the Meerwind Offshore Wind Farm project, the KfW development bank owned by the German Government provided initial financing which was then recycled during later phases of the project. For the WestConnex road project in Australia, the Government provided financial support for construction of initial phases, with the intention of selling its stake on completion in order to free up resources for investment in later stages.²³

UK pension funds place a lower priority on infrastructure investment than counterparts in some other countries, for example Canada. This may in part be because the UK pension fund landscape is more fragmented. In Canada, large funds such as the Ontario Municipal Employees Retirement Scheme have the necessary size to build up the expertise needed to manage complex infrastructure investments.

According to analysis by Cambridge Economic Policy Associates for the Commission, many UK pension funds and other institutional investors have in recent years been building capability to invest in infrastructure – whether directly themselves or indirectly through specialist infrastructure investment funds or investment platforms.²⁴

The Government has promoted creation of collective infrastructure investment platforms to harness the potential firepower of pension funds. Key examples include the Pensions Infrastructure Platform; GLIL, a joint venture between a number of pension funds including the London Pension Fund Authority and the Greater Manchester Pension Fund; and a potential Local Government Pension Scheme infrastructure platform.²⁵ It is important that momentum is maintained, so that pension funds with appetite to invest in infrastructure are able to access opportunities.

Some other countries develop appropriately detailed project pipelines, which are seen as desirable by investors. For example, the Netherlands has developed a successful pipeline for roads. By engaging early and strategically with the market, the Dutch Government has generated interest amongst the investor community. Competition amongst bidders has driven down costs. Similarly, communicating credibly that a number of projects will be delivered has encouraged potential investors to build their capability to bid for and manage roads projects. Again, this has reduced costs.²⁶

Non-profit distributing model

The non-profit distributing model has been developed in Scotland as an alternative to the Private Finance Initiative. The model caps returns to private investors by not allowing them to receive dividends from their shares – only regular availability payments. This arrangement provides private investors with a normal market rate of return, whilst ensuring that these returns are transparent. Where surpluses are made, these are paid to the public sector which can then reinvest these back into the project.

The model started being used for social infrastructure and is now being used for motorway improvements and for the construction of the new Aberdeen Western Peripheral Route.

More generally, investor confidence in and appetite for infrastructure investments can be built if underpinned by a clear policy direction set by the Government that offers long-term commitment and can attract patient capital.

The Commission's priorities

If the UK loses access to European Investment Bank financing and expertise, there will be a need to fill the gap created.

Any institutional solution to this could serve a range of functions, alongside or including the functions currently carried out by the UK Guarantee Scheme, depending on what eventually happens with the European Investment Bank and the Green Investment Bank. Possibilities include:

- Helping to enhance the creditworthiness of project developers, where this can make a project viable for investment, broaden the pool of investors who can invest in UK infrastructure, and efficiently bring down the cost of borrowing. This could include more systematic underwriting for local authorities, improving their creditworthiness.
- Playing a catalytic role in developing a pool of suitable investors for a market, for example by building investors' understanding of new technologies and types of project, and their appetite to invest in them. This could include the possibility of taking equity risk, where the bank puts in some of its own money as a co-investor.
- Acting as co-investor 'of last resort', for example providing investment where a project is too large for private investors or during periods of turbulence in financial markets. This is similar to the role that was played by the Government when it stood behind the project to widen the M25 as financier of last resort in the aftermath of the 2008 financial crisis.
- Addressing barriers to project financing that may emerge over time, for example in response to market trends and reform of regulations.
- Ensuring that a skill base similar to that within the European Investment Bank would remain available to the UK. Centralised expertise is used very effectively in markets such as Canada (e.g. Infrastructure Ontario) and in Australia. Such an approach could provide services to public sector project initiators enabling access to experience and enhancing delivery and assessment capacity around the country.

The LSE Growth Commission has proposed that a UK Infrastructure Bank should be created, in part to fill this gap. They also suggest it could help reduce policy risk, providing more stable long-term policy direction to infrastructure planners, investors and other key stakeholders.²⁷

A UK Infrastructure Bank would want to avoid restricting opportunities for private investors or crossing the line from helping markets function to backing unviable projects or technologies. Very clear guidelines would be needed to avoid 'crowding-out' or financing poor projects.

There are a number of development banks and financial institutions which could provide guidance on the type of role that a UK Infrastructure Bank could play. Two such institutions are summarised in the below box, although the very wide remit of these institutions may go beyond what would be needed in the UK.

The Chancellor of the Exchequer announced in June 2017 that he would engage to maintain access to the European Investment Bank for businesses and projects while the UK was still a member of the EU. Alongside this and looking forward to the post-Brexit medium term, the Chancellor announced an expansion of support available to capital funding in the UK, which will include broadening the range of the UK Guarantee Scheme by offering construction guarantees.²⁸ However, these schemes do not provide the same range of financial support as the European Investment Bank.

Models of state-sponsored infrastructure financing institutions

KfW IPEX-Bank

A legally independent subsidiary of Germany's development bank KfW, which is guaranteed by the German Government. KfW receives more than 90% of its funding through private capital markets, but also receives funding from the federal Government including loans.

KfW IPEX-Bank has mobilised private investors through its willingness to commit to long-term infrastructure projects. Its investments in infrastructure fit a wider remit to provide financing and growth support to the German and European economy, and it usually partners with other banks (including the EIB) to provide the initial financing in infrastructure projects. The bank has built up its institutional expertise over decades and provides its facilities, including loans and capital recycling, to domestic infrastructure projects, as well to those which support Germany's international connectivity – including aviation and railways.

Infrastructure Canada

A federal department, funded by the Canadian government, which has invested over C\$52 billion in over 1,000 projects in different sectors across the country. The bank provides support through a variety of mechanisms to local Government, the private sector and also not-for-profit infrastructure projects. Infrastructure Canada reports to Parliament and is managed by the Minister of Infrastructure and Communities.

The governance of any new institution would need to be sufficiently independent and robust. Political interference in investment decisions distorts efficient decision-making, and can undermine confidence. The European Investment Bank is structured to operate clearly at arm's length from Governments and any new institution should mirror this.

Other important considerations are the cost of and timeframe for establishing a new institution. Establishing a new bank would mean determining a clear direction and remit and building up capabilities. Some of these capabilities already exist within Government, but establishing a new organisation would take time. These factors would need to be considered when weighing up the merits of establishing a new institution relative to alternative Government interventions.

The design of any institution would also affect whether the Office for National Statistics classified it into the public sector. A public sector institution would impact on the public finances: most likely its liabilities would score as part of Public Sector Net Debt, the main debt measure used by the Government. The Government has set itself a target for Public Sector Net Debt to be falling as a percentage of GDP in 2020-21.²⁹

In contrast, the existing UK Guarantee Scheme does not score within Public Sector Net Debt, since guarantees are not classified as liabilities but only 'contingent liabilities' (i.e. they only get scored if the guarantee has to be called on). It is unlikely, but not impossible, that a UK Infrastructure Bank would also affect the Commission's fiscal remit.

In assessing the case for any institution, the Commission will seek to understand the full implications for the public finances and the fiscal risks that the Government is exposed to, as well as the impact on accounting aggregates. Unlike most public sector bodies, a UK Infrastructure Bank would hold financial assets paying a return. In a well-run body, these assets would more than match its liabilities and the returns would cover the institution's cost of capital. There would of course be some risk that assets failed to perform, but this risk is not fundamentally different to that involved in providing guarantees.

As part of the next stage of the Assessment, the Commission will consider options for filling any gap that may be left if access to the European Investment Bank is lost.

Whole life assessment of the costs and benefits of private finance

In assessing infrastructure financing options a careful and measured assessment is needed of the potential costs and benefits that may arise due to risk transfer to the private sector. Key areas include:

- Project management expertise: including the ability to manage delivery risk, cost over-runs during construction, and commissioning;
- Upfront design: often competitive procurement can provide the benefit of considering 3 or 4 different designs;
- Long term operation and maintenance: performance to a pre-agreed standard, with the potential for re-pricing if requirements change.

Government will almost always be able to finance projects more cheaply than the private sector. According to the National Audit Office, the cost of paying interest on private borrowing was double that of Government borrowing, but

information about individual projects is limited.³⁰ But these costs are not like-for-like comparisons. Different approaches to risk allocation need to be taken into account. Private investors typically bear the risk of a project directly. Public sector debt is not associated with specific projects: investors bear the risk of the Government as a whole, which can shift cost overruns or failure of any particular projects onto taxpayers. This lowers the cost of financing, since investors bear less risk. Even allowing for this, the Government will nearly always be able to borrow at lower cost because of the depth and liquidity of the market for UK Government debt ('gilts'), but the true difference in cost is typically less than the headline difference.

The choice between public and private finance should therefore depend on the overall balance of costs and benefits, assessed over the whole life of the project. Better evaluation of past projects would help inform future choices, ensuring that comparisons are not distorted by a focus on what is easily measured, rather than on the whole picture.

Private finance should not however be seen as a 'free pass' for projects that would not otherwise merit public funding. It remains important to ensure that projects brought forward are properly assessed against alternative uses of the future resources that are being committed.

As part of the next stage of the Assessment, the Commission will consider which new procurement and financing mechanisms might best meet infrastructure needs.

The Commission's vision

Meeting the Commission's vision would see the UK have:

- Access to the benefits of private sector investment and expertise in infrastructure, throughout the project lifecycle from construction to long-term maintenance provision.
- Efficient private finance for projects owned and funded in the private sector, with Government maintaining and building upon its range of mechanisms to support markets, both through the current period of uncertainty and in the long term.
- Public and private sectors working in partnership for projects owned and funded in the public sector, to identify where private sector finance and expertise can complement public funding to meet the UK's infrastructure needs with the best value for money.

Questions for consultation

The European Investment Bank and the Green Investment Bank have played an important role in financing infrastructure, but this may change following Brexit and privatisation of the Green Infrastructure Bank. The UK will need to have continued access to a similar range of services and expertise.

- 27) What would be the most effective institutional means to fulfil the different functions currently undertaken by the European Investment Bank if the UK loses access? Is a new institution needed? Or could an expansion of existing programmes achieve the same objectives?**

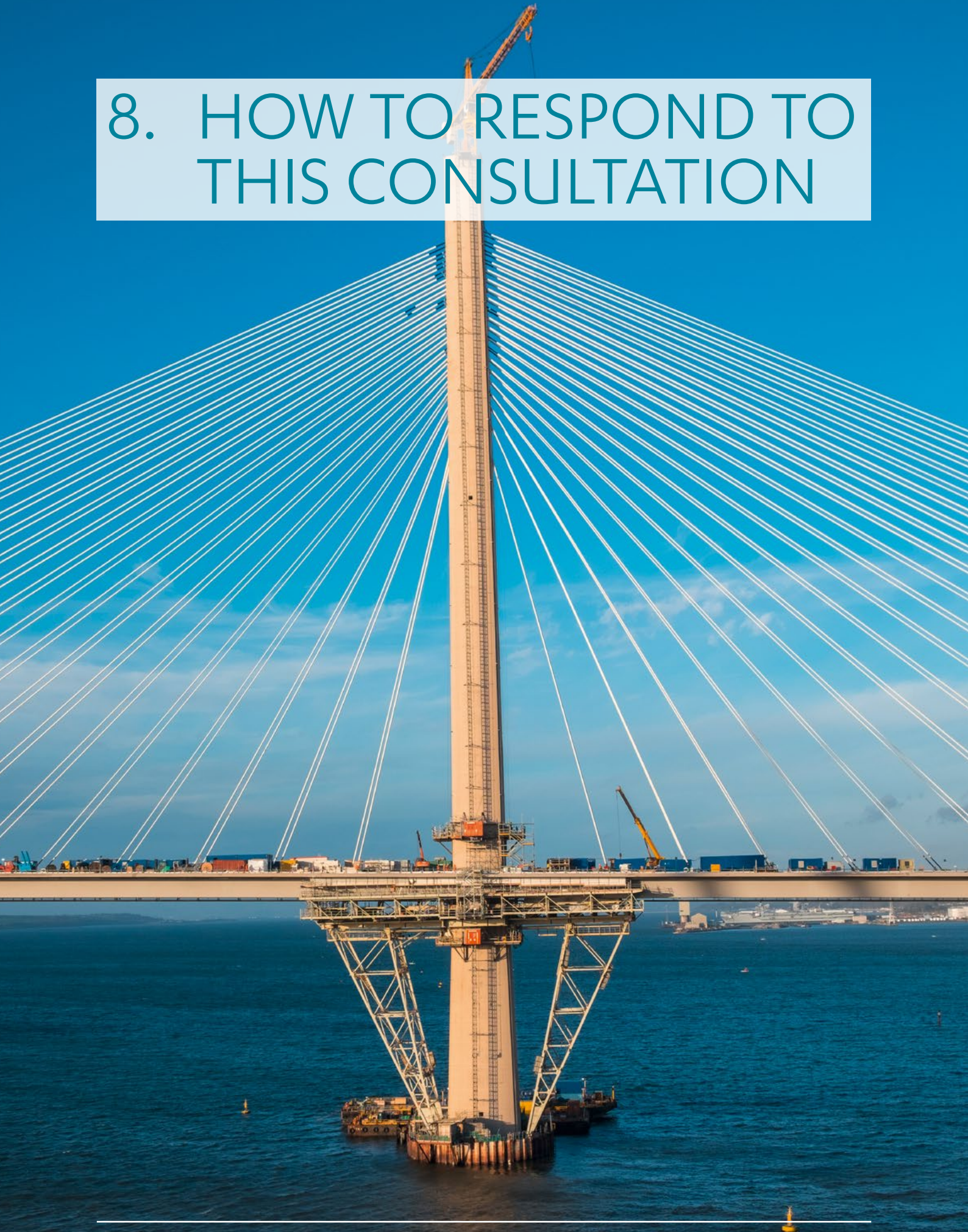
There is no widely accepted comparable data on the whole life costs and benefits of different financing models for publicly funded infrastructure. This may mean that opportunities are being missed to deliver projects more efficiently, at lower cost and sooner.

- 28) How could a comprehensive analysis of the costs and benefits of private and public financing models for publicly funded infrastructure be undertaken? Where might there be new opportunities for privately financed models to improve delivery?**

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8. HOW TO RESPOND TO THIS CONSULTATION



How to respond to this consultation

Your opinions are valuable to the Commission. Thank you for taking the time to read this document and respond. Responses to this consultation should be emailed to NIAEvidence@nic.gsi.gov.uk. Please provide responses by 12 January 2018.

Responses should be no longer than 20 sides of A4 paper. Respondents are welcome to answer all or only some of the questions set out (which are repeated below). Respondents are not required to base their submissions around these questions but they may find them helpful in providing a focus on issues that are likely to be important in the Assessment process.

Respondents are strongly encouraged to provide details of the evidence and data which support their positions. This will enable the Commission to understand more fully the basis on which those conclusions have been reached. The Commission will work with key local and national stakeholders as part of an open and transparent process of engagement to support the consultation. In addition to its publications and the consultations that it carries out, the Commission's engagement tools include the use of expert advice and challenge, discussions with local, regional and national stakeholders, subject-focussed seminars and social research.

In addition to this document, the Commission intends to publish further evidence and analysis ahead of the final National Infrastructure Assessment. This may include external analysis produced for the Commission as well as the Commission's own analysis and thinking on the issues covered by the National Infrastructure Assessment. Respondents are welcome to comment on these publications: details on how to do so will be set out alongside them.

In exceptional circumstances, the Commission will accept submissions in hard copy only. If you need to submit a hard copy, please send your response to the Commission secretariat at the address below:

National Infrastructure Assessment consultation
National Infrastructure Commission
5th Floor
11 Philpot Lane
London EC3M 8UD

The Commission is subject to legal duties which may require the release of information under the Freedom of Information Act 2000 or any other applicable legislation or codes of practice governing access to information.

The Commission may publish any submissions made. If you want the information that you provide to be treated as confidential, please be aware that, under the Freedom of Information Act 2000, there is a statutory code of practice with which public authorities must comply and which deals, amongst other things, with obligations of confidence. The Commission is within the scope of the Freedom of Information Act. In view of this it would be helpful if you could explain why you regard the information you have provided as confidential. If a request for disclosure

of the information is received, the Commission will take full account of your explanation but cannot give an assurance that confidentiality can be maintained in all circumstances. An automatic confidentiality disclaimer generated by your IT system will not, of itself, be regarded as binding on the Commission.

The Commission will process your personal data in accordance with the Data Protection Act 1998 and in the majority of cases this will mean that your personal data will not be disclosed to third parties. Individual responses will not be acknowledged unless specifically requested.

Are you satisfied with this consultation? If not, or you have any other observations about how we can improve the process, please contact the Commission at:

NIAEvidence@nic.gsi.gov.uk

Consultation Questions

- 1) *How does the UK maximise the opportunities for its infrastructure, and mitigate the risks, from Brexit?*
- 2) *How might an expert national infrastructure design panel best add value and support good design in UK infrastructure? What other measures could support these aims?*
- 3) *How can the set of proposed metrics for infrastructure performance (set out in Annex A) be improved?*
- 4) *Cost-benefit analysis too often focuses on producing too much detail about too few alternatives. What sort of tools would best ensure the full range of options are identified to inform the selection of future projects?*
- 5) *What changes are needed to the regulatory framework or role of Government to ensure the UK invests for the long-term in globally competitive digital infrastructure?*
- 6) *What are the implications for digital infrastructure of increasing fixed and mobile convergence? What are the relative merits of adding more fibre incrementally over time compared to pursuing a comprehensive fibre to the premises strategy?*
- 7) *What are the key factors including planning, coordination and funding, which would encourage the commercial deployment of ubiquitous connectivity (including, but not only, in rural areas)? How can Government, Ofcom and the industry ensure this keeps pace with an increasingly digital society?*
- 8) *How can the risks of 'system accidents' be mitigated when deploying smart infrastructure?*
- 9) *What strategic plans for transport, housing and the urban environment are needed? How can they be developed to reflect the specific needs of different city regions?*

- 10) *What sort of funding arrangements are needed for city transport and how far should they be focused on the areas with the greatest pressures from growth?*
- 11) *How can the Section 106 and Community Infrastructure Levy regimes be improved to capture land and property value uplift efficiently and help fund infrastructure? Under what conditions are new mechanisms needed?*
- 12) *What mechanisms are needed to deliver infrastructure on time to facilitate the provision of good quality new housing?*
- 13) *What will the critical decision factors be for determining the future of the gas grid? What should the process for deciding its future role be and when do decisions need to be made?*
- 14) *What should be the ambition and timeline for greater energy efficiency in buildings? What combination of funding, incentives and regulation will be most effective for delivering this ambition?*
- 15) *How could existing mechanisms to ensure low carbon electricity is delivered at the lowest cost be improved through:*
 - *Being technology neutral as far as possible*
 - *Avoiding the costs of being locked in to excessively long contracts*
 - *Treating smaller and larger generators equally*
 - *Participants paying the costs they impose on the system*
 - *Bringing forward the highest value smart grid solutions*
- 16) *What are the critical decision factors for determining the role of new nuclear plants in the UK in scenarios where electricity either does, or does not, play a major role in the decarbonisation of heat? What would be the most cost-effective way to bring forward new generation capacity? How important would it be for cost-effectiveness to have a fleet of nuclear plants?*
- 17) *What are the critical decision factors for determining the role of carbon capture and storage in the UK in scenarios where electricity either does, or does not, play a major role in the decarbonisation of heat? What would be the most cost-effective way to bring it forward?*
- 18) *How should the residual waste stream be separated and sorted amongst anaerobic digestion, energy from waste facilities and alternatives to maximise the benefits to society and minimise the environmental costs?*
- 19) *Could the packaging regulations be reformed to sharpen the incentives on producers to reduce packaging, without placing disproportionate costs on businesses or creating significant market distortions?*

20) *What changes to the design and use of the road would be needed to maximise the opportunities from connected and autonomous vehicles on:*

- *motorways and 'A' roads outside of cities?*
- *roads in the urban environment?*

How should it be established which changes are socially acceptable and how could they be brought about?

21) *What Government policies are needed to support the take-up of electric vehicles? What is the role of Government in ensuring a rapid rollout of charging infrastructure? What is the most cost-effective way of ensuring the electricity distribution network can cope?*

22) *How can the Government best replace fuel duty? How can any new system be designed in a way that is fair?*

23) *What should be done to reduce the demand for water and how quickly can this have effect?*

24) *What are the key factors that should be considered in taking decisions on new water supply infrastructure?*

25) *How can long-term plans for drainage and sewerage be put in place and what other priorities should be considered?*

26) *What investment is needed to manage flood risk effectively over the next 10 to 30 years?*

27) *What would be the most effective institutional means to fulfil the different functions currently undertaken by the European Investment Bank if the UK loses access? Is a new institution needed? Or could an expansion of existing programmes achieve the same objectives?*

28) *How could a comprehensive analysis of the costs and benefits of private and public financing models for publicly funded infrastructure be undertaken? Where might there be new opportunities for privately financed models to improve delivery?*

Annex A: Performance measures

As part of the evidence base for the Assessment, the Commission intends to develop a concise set of relevant performance measures that can be used to consider the current performance and shortcomings of the UK's economic infrastructure. The Commission is focused on a small set of high-level measures, which relate to its objectives. As far as possible, these measures would be cross-sectoral (combined with a sector breakdown) or apply similar concepts across different sectors. The Commission does not intend to replicate the work of other organisations, who may be looking at other and more detailed measures.

The measures in the table below were identified through a review of current sector, national and international measures, consultation with a wide range of external stakeholders and analysis from JBA working with SDG Economic Development, Temple and GreySky. Further details of this work are available on the Commission's website.

Some of the measures are existing measures that are already collected regularly, while others will require further work. In some cases, that work might extend beyond the first Assessment, especially if new data are needed. The Commission welcomes stakeholder views on all the proposed measures, and would be particularly interested in methodological suggestions where measures do not currently exist.

Any design quality measure would be developed in concert with the proposed expert national infrastructure design panel (see Introduction). The Commission also continues to work with the Natural Capital Committee with a view to including one or more measures of the interaction between infrastructure and natural capital in future.

	Transport	Energy	Waste	Water	Flood Risk	Digital Comms
Resilience to large shocks	<ul style="list-style-type: none"> Stress test⁽ⁿ⁾ 	<ul style="list-style-type: none"> Capacity margin^(e) Expected loss of load^(e) Diversity of energy sources^(e) 	<ul style="list-style-type: none"> Capacity margin^(e) 	<ul style="list-style-type: none"> Risk of drought⁽ⁿ⁾ 	<ul style="list-style-type: none"> Risk of flooding and coastal erosion^(e) Standard of protection⁽ⁿ⁾ 	<ul style="list-style-type: none"> Stress test⁽ⁿ⁾
Everyday resilience	<ul style="list-style-type: none"> Travel time reliability⁽ⁿ⁾ 	<ul style="list-style-type: none"> Time that properties lose access to energy^(e) 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> Time that properties lose access to water^(e) Number of sewer flood events^(e) 	<ul style="list-style-type: none"> Number of properties flooded^(e) 	<ul style="list-style-type: none"> Time that properties lose access to digital signal^(e)
Service quality	<ul style="list-style-type: none"> Connectivity – the effectiveness of the network at getting people from A to B⁽ⁿ⁾ 	<ul style="list-style-type: none"> Energy efficiency of buildings^(e) Peak load shifting^(e) Smart meters in operation^(e) 	<ul style="list-style-type: none"> Recycling rates^(e) Energy from waste^(e) 	<ul style="list-style-type: none"> Number of water quality incidents^(e) Water leakage^(e) 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> Maximum possible speed^(e) Coverage by technology^(e)
Quality of user experience	<ul style="list-style-type: none"> Satisfaction derived from survey^(e) Design quality⁽ⁿ⁾ 	<ul style="list-style-type: none"> Satisfaction derived from survey⁽ⁿ⁾ Design quality⁽ⁿ⁾ 	<ul style="list-style-type: none"> Design quality⁽ⁿ⁾ 	<ul style="list-style-type: none"> Satisfaction derived from survey^(e) Design quality⁽ⁿ⁾ 	<ul style="list-style-type: none"> Design quality⁽ⁿ⁾ 	<ul style="list-style-type: none"> Satisfaction derived from survey^(e) Design quality⁽ⁿ⁾ Sold speed experienced⁽ⁿ⁾
Cost	<ul style="list-style-type: none"> Cost per passenger/tonne km⁽ⁿ⁾ 	<ul style="list-style-type: none"> Cost per kWh of energy^(e) Average annual bill^(e) 	<ul style="list-style-type: none"> Cost per tonne of waste disposed or treated^(e) 	<ul style="list-style-type: none"> Cost per litre of water abstracted^(e) Average annual bill^(e) 	<ul style="list-style-type: none"> Cost per property protected⁽ⁿ⁾ 	<ul style="list-style-type: none"> Cost per GB of data^(e) Average annual bill^(e)
Emissions	<ul style="list-style-type: none"> gCO₂e emissions per passenger/tonne km⁽ⁿ⁾ 	<ul style="list-style-type: none"> Emissions intensity of energy consumption in gCO₂e per kWh^(e) 	<ul style="list-style-type: none"> gCO₂e emissions per average kg of waste produced per person⁽ⁿ⁾ 	<ul style="list-style-type: none"> gCO₂e emissions per average L of water consumed per person⁽ⁿ⁾ 	<ul style="list-style-type: none"> N/A 	<ul style="list-style-type: none"> gCO₂e emissions per average GB of traffic per person⁽ⁿ⁾
Environmental externalities	<ul style="list-style-type: none"> Air quality^(e) Noise^(e) 	<ul style="list-style-type: none"> Air quality^(e) 	<ul style="list-style-type: none"> Waste generated per capita^(e) 	<ul style="list-style-type: none"> Quality of rivers and sea^(e) Degree to which environmental flows are maintained⁽ⁿ⁾ 	<ul style="list-style-type: none"> Measure of habitat improved or created^(e) 	<ul style="list-style-type: none"> N/A

Note: ^(e) denotes existing measures; ⁽ⁿ⁾ denotes new measures

Annex B: Acknowledgements

The Commission is grateful to everyone who has engaged with the National Infrastructure Assessment process so far.

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- assisting the Commission in developing its modelling outputs;
- hosting or attending its regional meetings, sector workshops, expert and/or driver roundtables;
- responding to the Commission's consultation on the Process and Methodology for the Assessment or the Call for Evidence on the Assessment.

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Able Connections	Analysys Mason
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ADEPT	Angel Trains
AECOM	Anglia Ruskin University
Affinity Water	Anglian Water
Age UK	Anthesis
Aggregate Industries	Arcadis
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Alderney Renewable Energy	Arup
Aldersgate Group	Aspley Guise Parish Council
All Party Parliamentary Light Rail Group	Associated British Ports (ABP)
Allianz Global Investors	Association for Consultancy and Engineering (ACE)
Alstom Transport	
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Business Services Association (BSA)
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Cambridge Economic Policy Associates (CEPA)
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Campaign to Protect Rural England (Kent branch)
Canal and River Trust
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Carbon Capture and Storage Association (CCSA)
Carillion
Carmarthenshire County Council
CAS Solutions
CAUSE
Centre for Cities
Centre for Connected and Autonomous Vehicles (CCAV)
Centre for Progressive Capitalism

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Centre for Sustainable Energy	Coastline Housing
Centre for the Understanding of Sustainable Prosperity (CUSP), University of Surrey	Committee on Climate Change (CCC)
Centre for Transport Studies, University College London	Committee on Fuel Poverty
Centre for Water Systems, University of Exeter	Common Futures Network
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Centrica	Community Support
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CH2M	Confederation of British Industry (CBI)
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Chartered Institute of Building (CIOB)	Connected Cities
Chartered Institute of Logistics and Transport	Construction Employers Federation, Northern Ireland
Chartered Institution of Building Services Engineers (CIBSE)	Construction Industry Research and Information Association (CIRIA)
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ClientEarth	Coventry University
Coast to Capital LEP	Crane Building Services and Utilities
	Cranfield School of Management
	Cranfield University
	Cranswick
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Dorset LEP	Energy Policy Research Group (EPRG), University of Cambridge
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East Midlands Councils	Environment Agency (EA)

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FirstGroup
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Strategic Investment Board
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Viridor	WSP
Vivergo Fuels	WWF
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