

NATIONAL INFRASTRUCTURE ASSESSMENT



**NATIONAL
INFRASTRUCTURE
COMMISSION**

July 2018

Contents

The Commission	2
Foreword	3
In brief	5
Executive summary	6
1. Building a digital society	17
2. Low cost, low carbon	31
3. Revolutionising road transport	51
4. Transport and housing for thriving city regions	67
5. Reducing the risks of drought and flooding	83
6. Choosing and designing infrastructure	99
7. Funding and financing	109
8. Next Steps	125
Annex A: Glossary	131
Annex B: Acknowledgements	142
Annex C: Supplementary documents	151
Annex D: Recommendations	154

The Commission

The National Infrastructure Commission was established in 2015 to provide independent, impartial advice on the UK's long term infrastructure needs.

As of July 2018, the Commission's members are:

Sir John Armitt CBE (Chair) published an independent review on long-term infrastructure planning in the UK in September 2013, which resulted in the National Infrastructure Commission. Sir John is chairman of the National Express Group and the City & Guilds Group and sits on the boards of the Berkeley Group and Expo 2020.

Dame Kate Barker sits on the boards of Taylor Wimpey plc and Man Group plc. She is also chair of trustees for the British Coal Staff Superannuation Scheme. She has previously served as an external member of the Bank of England's Monetary Policy Committee (2001-2010).

Professor Sir Tim Besley CBE is School Professor of Economics and Political Science and W. Arthur Lewis Professor of Development Economics at the LSE. He has previously served as an external member of the Bank of England Monetary Policy Committee (2006-2009).

Professor David Fisk CB is Emeritus Professor at the Centre for Systems Engineering and Innovation at Imperial College London. He has served as Chief Scientist across several Government departments including Environment and Transport, and as a member of the Gas and Electricity Markets Authority.

Andy Green holds several Chairman, Non-Executive Director and advisory roles, linked by his passion for how technology transforms business and people's daily lives. This includes chairing IG Group, a global leader in online trading and Digital Catapult, an initiative to help grow the UK digital economy.

Professor Sadie Morgan is a founding director of the Stirling Prize winning architecture practice dRMM. She is also chair of the Independent Design Panel for High Speed Two, is deputy chair of the Thames Estuary 2050 Growth Commission and a Mayor's design advocate for the Greater London Authority.

Julia Prescott is co founder and Chief Strategy Officer of Meridiam, and sits on the Executive Committee of Meridiam SAS. She has been involved in long term infrastructure development and investment in the UK, Europe, North America and Africa.

Bridget Rosewell OBE is a director, policy maker and economist. She has served as Chief Economic Adviser to the Greater London Authority (2002-2012) and worked extensively on infrastructure business cases. She is a director of Network Rail.

Foreword

The infrastructure we have now, and the infrastructure we plan to build, will support and sustain us for decades to come. Our quality of life, and our success as an economy in the future, will depend on our infrastructure's ability to respond to future challenges. This will rely on decisions taken now.

Providing the right infrastructure for the future does not just entail delivering the running water, roads and rail that traditionally spring to mind, although these are important. The UK needs fast, reliable internet connections. It needs low cost energy and transport that doesn't harm the planet. It needs to make cities liveable for the growing urban population. It needs to reduce the plastic waste that can end up in our oceans. It needs water supply and flood defences that can respond to the risk of extreme floods and drought. All this needs to be done in a way that is well designed, and affordable for the government and the public.

Over the last 50 years, the UK has seen an endless cycle of delays, prevarication and uncertainty. These have been driven in part by short term considerations, and the lack of a cross-sectoral approach to infrastructure. This approach has limited growth, undermined job certainty, and restricted innovation. And too often the UK has ended up playing catch up. This will not do for the challenges ahead.

In the National Infrastructure Assessment, the first of its kind, the Commission has been able to look across infrastructure sectors, and come to independent conclusions based on the best available evidence. The Assessment sets out a clear, long term strategy for the UK's economic infrastructure from 2020 to 2050, providing long term clarity for industry and the supply chain.

The Commission's interim report, published in October 2017, identified three headline challenges for the UK's infrastructure: congestion, capacity and carbon. The Assessment's recommendations to government tackle congestion by prioritising devolved, stable, long-term funding for urban infrastructure in cities. The recommendations will improve the capacity of our water supply and digital infrastructure. And they will reduce our carbon emissions by leading the move to an energy system that is powered mainly by renewable energy sources such as solar and wind.

However, this is not all: the recommendations will also improve our quality of life by reducing air pollution, protecting our homes from floods, and making cities better places to live. The cost of driving will fall substantially if people can switch to electric vehicles. And they will help the environment by reducing waste that ends up in our landfills, incinerators and oceans.

Over the course of preparing this Assessment, the Commission has consulted and listened to the public, industry, academics, local and national government. Our analysis and proposals will not satisfy everyone. But the recommendations represent our considered view of how we can best create infrastructure which enables a fair, productive and green society for the whole country.

Ensuring that the Commission's recommendations can deliver the benefits we think they can, will require politicians across all parties to build a consensus. We welcome the funding guidelines that government has set for the Commission's recommendations, and have made our recommendations in line with it. We have also taken into account existing government commitments for road, rail and aviation, as well as all of our previous recommendations. We look forward to the government adopting our programme of recommendations as policy, and committing to invest in our infrastructure over the coming years.

I would like to take this opportunity to thank my fellow Commissioners and the excellent team at the Commission secretariat, in particular its Chief Economist, James Richardson, who has led the development of this Assessment from start to finish. I would also like to thank everyone who has contributed to our work over the last two years. We look forward to the response from government and the wider community.



Sir John Armitt CBE
Chair, National Infrastructure Commission

In brief

The first National Infrastructure Assessment sets out the Commission's plan of action for the country's infrastructure over the next 10-30 years. Infrastructure can inspire confidence and growth. But long term projects require a long-term vision, lasting plans, and stable funding. The UK must take decisive action.

The Commission's recommendations represent a significant programme of upgrades to the nation's infrastructure. But they are not an unaffordable wish list. They have been costed in line with the government's guideline for investment in infrastructure. And they are affordable for households and businesses.

The Commission was set up to address the lack of a long term infrastructure strategy, siloed decision making in infrastructure sectors, fragile political consensus and short termism. The Commission has addressed these issues by taking a long term, cross-sectoral approach, with in-depth analysis and wide consultation.

The government has committed to respond to the Commission's recommendations and to adopt agreed recommendations as government policy.

The recommendations set out a pathway for the UK's economic infrastructure:

- nationwide full fibre broadband by 2033
- half of the UK's power provided by renewables by 2030
- three quarters of plastic packaging recycled by 2030
- £43 billion of stable long term transport funding for regional cities
- preparing for 100 per cent electric vehicle sales by 2030
- ensuring resilience to extreme drought
- a national standard of flood resilience for all communities by 2050.

Alongside these, better design and more efficient funding and financing can save money, reduce risk, add value and create a legacy that looks good and works well.

These recommendations will equip the UK with the infrastructure it most needs. The Commission will continue to work to build consensus. It will hold government to account for the implementation of its recommendations. And it will continue to work on the nation's most pressing infrastructure issues.

Executive summary

The UK must take decisive action to have world leading infrastructure. Infrastructure can inspire confidence and growth. But long term projects require a long term vision, lasting plans, and stable funding.

Too often, the delivery of the UK's major infrastructure projects has been slow and uncertain. Airport expansion in the south east is the best known, but not the only, example. The Mersey Gateway Bridge, which opened in October 2017, was proposed in 1994. Crossrail, due to open this year, was originally proposed in 1974. Consequently, much of the country's infrastructure has not kept pace with population growth, demand and advances in technology. The UK must stop running to stand still.

The National Infrastructure Commission was set up to address the problems with long term infrastructure planning in the UK. This first National Infrastructure Assessment builds on the analysis in the Commission's interim report, *Congestion, Capacity, Carbon: Priorities for national infrastructure*, to set out a long term vision for high quality, good value, sustainable economic infrastructure for the UK, and a clear plan to achieve it.

Its core proposals include:

- nationwide full fibre broadband by 2033
- half of the UK's power provided by renewables by 2030
- three quarters of plastic packaging recycled by 2030
- £43 billion of stable long term transport funding for regional cities
- preparing for 100 per cent electric vehicle sales by 2030
- ensuring resilience to extreme drought through additional supply and demand reduction
- a national standard of flood resilience for all communities by 2050.

It also highlights the most important future challenges. Heating must no longer be provided by natural gas, a fossil fuel. The UK must prepare for connected and autonomous vehicles. These need more time for evidence or technology to develop. The Assessment sets out the actions needed to enable robust decisions to be taken in future.

The National Infrastructure Assessment

The Commission is required to carry out an overall assessment of the UK's infrastructure requirements once every 5 years. This is the first of those assessments. It covers all the key sectors of economic infrastructure, setting out recommendations for transport, energy, water and waste water, flood resilience, digital connectivity, and solid waste, from now until 2050. The Commission's remit also includes the potential interactions between its infrastructure recommendations and housing, but not housing supply in general. The Assessment 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. More information can be found in the Commission's **framework document**.

Thinking long term

By 2050, the UK's population and economy will have grown significantly. This will place substantial pressures on infrastructure. And meeting the challenge of climate change will require a transformation in energy, waste and transport by 2050. Even so, the effects of climate change will still be felt, with higher average temperatures and increased risk of drought and flooding. The UK's infrastructure will need to adapt to these pressures. The Assessment provides a long term strategy for how to do this. More information can be found in the Commission's four papers on **the environment and climate change, economic growth, population change and demography, and technological change**.

How has the Commission come to these conclusions?

The strategies have been developed considering the responses to the Commission's consultation in **Congestion, Capacity, Carbon: Priorities for national infrastructure**, working closely with experts and other independent organisations, seeking diverse views across sectors and regions, asking the public for their views (via a social research programme), and through the Commission's own internal analysis and modelling. More information and consultants' reports can be found on the Commission's **website**.

How much will this all cost?

Government has given the Commission a long term funding guideline for its recommendations (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 also required to provide a transparent assessment of the overall impact on bills. These are set out in Chapter 7. More information on the Commission's fiscal and economic remit can be found in the Commission's **remit letter**.

The Commission's recommendations represent a major long term programme of investment in the UK's infrastructure. The programme includes substantial funding for major schemes such as Crossrail 2 and Northern Powerhouse Rail, as well as to support the delivery of enhanced digital networks and flood protection. The Assessment has been made in the light of existing infrastructure plans and investment. However, this is not an unaffordable wish list, but has been carefully designed to be consistent with the government's long term funding guideline for public investment in infrastructure. Where infrastructure is funded by the private sector, a transparent assessment is provided of costs and savings for each recommendation to ensure that consumer costs are manageable and proportionate to the benefits the infrastructure provides.

The recommendations in this Assessment have all been guided by the objectives set for the Commission by government to: support sustainable economic growth across all regions of the UK; improve competitiveness; and improve quality of life. They have been designed to stand the test of time, and to be robust to a variety of scenarios. Together they comprise an ambitious plan to modernise and enhance the UK's economic infrastructure.

The Assessment's recommendations do not simply comprise a list of projects for the government to build; good infrastructure requires long term planning, stable funding structures and good design. The Commission has also been able to consider interdependencies between sectors: urban infrastructure planning needs to be integrated with housing; the energy system needs to be prepared for an increase in electric vehicle ownership; and digital connectivity on the roads could be necessary for connected and autonomous vehicles.

Further detail on the Commission's analysis is set out in the technical annexes published alongside this report, the Commission's interim report and background papers, and the 31 reports commissioned for the Assessment, available on the Commission's website. Annex C sets out a list of these supplementary documents.

Good infrastructure is essential to the country's future growth and prosperity. Infrastructure is a key pillar of the government's Industrial Strategy. Now is the time to deliver. This Assessment is the plan of action.

Building a digital society

Data and digital connectivity will increasingly drive the country's economic growth, competitiveness, and quality of life. Digital communication makes it easier for customers and suppliers to find each other and exchange goods and services. In future, innovations such as artificial intelligence and the internet of things will bring new applications that rely on digital connectivity, from driverless cars to increased use of virtual reality. Some health services are already moving online, providing better access to specialist services, and reducing the need for patients to sit in waiting rooms where they risk further infection.

The UK already has a strong digital economy underpinned by an extensive broadband network. But the superfast broadband programme that delivered this is coming to an end. While current digital connectivity is enough for current needs, demand for data is rapidly increasing; superfast broadband may not be sufficient for the future.

The Commission's judgement is that the government should act now to deliver full fibre across the country; in the Commission's social research, 86 per cent of people agreed that all parts of the UK should have equal access to broadband. Full fibre broadband is the likely next step in digital connectivity. It is more reliable and cheaper to maintain than today's part copper, part fibre broadband connections. But it will take at least a decade to build nationally. Government needs to make a decision on full fibre now to avoid the risk of the UK being left behind in years to come. Full fibre will deliver benefits compared to current broadband even if the expected demand growth does not materialise. Enhanced digital connectivity will also facilitate the development of smart infrastructure: infrastructure with digital connections, enabling more efficient management and maintenance.

To encourage full fibre rollout, the government should put in place a national broadband plan by the end of 2018. Ofcom should provide certainty to commercial investors and encourage further private sector delivery of full fibre. With this certainty from government and Ofcom, most urban areas are likely to receive full fibre just through the promotion of market competition. However, full fibre will still need to be subsidised in some areas where commercial players are unlikely to deliver it. This should begin with the locations least likely to receive broadband commercially. With these plans in place, nationwide full fibre connectivity should be available no later than 2033.

Low cost, low carbon

The UK can and should have low cost and low carbon electricity, heat and waste. Ten years ago, it seemed almost impossible that the UK would be able to be powered mainly by renewable energy in an affordable and reliable way. But there has been a quiet revolution going on in this area. There is ample scope to build on this success in years to come. Highly renewable, clean, and low cost energy and waste systems increasingly appear to be achievable.

Furthermore, such a system need not lead to higher bills. Today, consumers pay an average of £1,850 per year for the energy they use, including fuel and equipment for heating and hot water, electricity and transport fuel costs. The same services could be delivered at the same cost (in today's prices) in 2050 by a low carbon energy system. But this will only be possible if the right decisions are taken now.

Sustaining progress on reducing emissions requires government to show ambition. The crucial first step is to enable an increasing deployment of renewables. The Commission's modelling has shown that a highly renewable generation mix is a low cost option for the energy system. The cost would be comparable to building further nuclear power plants after Hinkley Point C, and cheaper than implementing carbon

capture and storage with the existing system. The electricity system should be running off at least 50 per cent renewable generation by 2030, as part of a transition to a highly renewable generation mix. Government should not agree support for more than one nuclear power station beyond Hinkley Point C before 2025.

But there are some changes that will need to be made to enable the increase in renewables. It will require increased system flexibility, in line with the recommendations in the Commission's *Smart Power* report. The Commission favours the use of existing market mechanisms – contracts for difference and the capacity market – where possible, to avoid creating more uncertainty, but incremental improvements could be made. All renewables should be able to compete; there is no longer a case for any bilateral deals, including for tidal.

Even with emissions almost eliminated from power generation, the UK cannot achieve its emissions targets while relying on natural gas, a fossil fuel, for heating. Delivering a low cost, low carbon heating system is the major outstanding challenge. But the electricity system represented just such a challenge ten years ago. There are actions that the UK can and should take now.

As a first step, improving the energy efficiency of the UK's buildings will mitigate some of the emissions from heat. In the meantime, the evidence base must be built up to make decisions on heat in future. The safety case for using hydrogen as a replacement for natural gas should be established, followed by trials for hydrogen at a community scale and alongside carbon capture and storage. At the same time, further data on the performance of heat pumps in the UK should be collected and used to support decisions.

In the waste sector, too, there are lower cost, lower carbon options especially for food waste and plastics. There is public support for greater recycling, but frustration with the complexity of the process.

It is cheaper to collect food waste separately and process it in anaerobic digesters, rather than send it to energy from waste plants (incinerators). Seventy nine per cent of people who do not currently use a food waste bin would be prepared to use one if it were provided by their local council. More plastics should be recycled, including by restricting the use of hard-to-recycle plastic packaging by 2025. Better packaging design, clearer labelling, fewer hard to recycle plastics, and tougher recycling targets (of 65 per cent of municipal waste and 75 per cent of plastic packaging by 2030) could all reduce residual waste and mitigate the need to build additional infrastructure.

Revolutionising road transport

By 2050, road transport will be unrecognizable from today. Cars and vans will be electric, and increasingly autonomous. Electric, connected and autonomous vehicles will change the nature of the transport debate in the UK.

Electric vehicles are easier to drive, quieter and less polluting than conventional cars and will soon have the same range and be cheaper to buy and maintain. Once

this happens, their take up could increase rapidly. Given their benefits for the environment, this is something government should encourage. A key way to do this is by ensuring that charging an electric vehicle is as easy as refilling a conventional vehicle, or even easier.

The government needs to provide the right environment to support and encourage the switch to electric vehicles. To catalyse this, consumers need to feel confident that they can charge their electric vehicles en route across the country. A core network of fast or rapid chargers should be installed in visible locations across the UK. Government should subsidise charger installation where the private sector will not build them, starting in the locations least likely to be delivered commercially. However, the majority should be built by the private sector. Government should enable commercial investors to build charge points throughout the country, including by requiring local authorities to free up 5 per cent of their parking spaces for electric vehicle charge points by 2020, and 25 per cent by 2025.

The energy system will also need to be prepared for an increase in demand for electricity as the transition to electric vehicles gains traction. Whilst fast and rapid chargers will be needed to tackle range anxiety, most charging should be slow and smart. Done in the right way, using smart charging, electric vehicles can lower electricity system costs: the system will be able to operate closer to full capacity over the course of the day, as electric vehicles can charge primarily at night, increasing network efficiency. And with electric vehicles providing a source of flexible demand, the need for other kinds of flexibility such as battery storage or fossil fuels will be reduced.

In the longer term, connected and autonomous vehicles will bring even greater changes to the UK's roads. They will improve safety, and could allow more people to use personal transport and free up driving time for work or leisure. They may even encourage a shift towards increased vehicle sharing and reduced car ownership. Traffic lights and stop signs may become unnecessary, speed limits could be higher, and the use of road space could be automatically and constantly changing according to need. But, with road and rail projects lasting for decades, government needs to start taking the potential future impacts into account now as it makes investment plans.

A framework should be developed to assess potential impacts, even though these are inevitably uncertain. An initial framework should be put together before the next five year planning cycle for rail and major roads begins in the early 2020s.

Transport and housing for thriving city regions

Cities can be great places to live, with excellent public transport systems, well-designed public spaces for leisure and social activities, and flourishing, well-connected businesses. They are also engines of economic growth. However, as urban populations increase, many cities are becoming full and congested, and this is inhibiting economic development and reducing quality of life.

The UK has a programme of major strategic transport projects in the pipeline, including a large programme to improve major roads, HS2 and Northern Powerhouse Rail. In planning for the next wave of major investment, attention must be turned to cities. The UK is unusual in that many of its large cities outside of the capital are less productive than the national average. Transport alone cannot drive growth, but the UK should make sure that urban transport enables it.

For all their benefits, neither electric nor connected and autonomous vehicles will solve the problems of urban transport; rather they are likely to increase the number of drivers on the roads. Government and cities need to act now to ensure that space in cities is used effectively, with room allocated for fast, frequent public transport systems, well-connected and affordable housing, and pleasant public spaces. This will require a new approach to governance, strategy and funding.

To deliver thriving cities, metro mayors and other city leaders should develop integrated strategies for transport, employment and housing. Housing and infrastructure should be planned together: new housing requires new infrastructure. These integrated strategies should be backed up by stable, substantial, devolved funding. And for the cities that face the most severe capacity constraints, and with the most potential for growth, there should be additional funding to support major upgrade programmes, which would be agreed between the cities and central government.

Development of regional cities should be in addition to, rather than instead of, continuing to invest in London, whose growth brings benefits across the UK. The Commission will continue to work with government and cities to develop the next wave of infrastructure upgrades across the country.

Reducing the risks of drought and flooding

Climate change will continue to make extreme weather events such as floods and drought more likely in future years, and cities, towns and villages must be resilient. Decisive policy action is needed to mitigate these risks.

About 5 million properties in the UK are currently at risk of flooding. Protection from floods in the UK over the past years has too often been reactive rather than proactive. Ideally, no one should be exposed to flooding. Flooding has severe impacts on quality of life, particularly mental health.

A long term strategy for flood protection would allow a nationwide standard of resilience to flooding, with catchment based plans. These plans should evaluate the full range of options including traditional flood defences, 'green infrastructure' (whether natural flood management or sustainable drainage systems), individual property measures and spatial planning. In the Commission's social research, 59 per cent of people agreed that everyone should have the same standard of flood resilience, even though some properties cost more to protect.

The Commission believe that a national standard should be set for resilience to flooding with an annual likelihood of 0.5 per cent by 2050, where feasible. Over

longer time periods, higher standards might be achievable. Densely populated areas, where the consequences of flooding are potentially much more serious, should be resilient to flooding with a likelihood of only 0.1 per cent a year by 2050. The Environment Agency should update plans for all catchments and coastal cells in England before the end of 2023.

A reliable water supply is usually taken for granted in UK. But despite its reputation for rain, the country faces a real and growing risk of water shortages, especially in the south east of England. Action is needed to address these challenges, but conflicting incentives, limited cooperation between water companies and a short term focus mean that insufficient progress has been made. In the event of a serious drought, the nation faces an unacceptably high risk of severe supply limitations; homes and businesses could even be completely cut off.

The Commission has published a standalone report, *Preparing for a drier future: England's water infrastructure needs*, which sets out a twin-track approach to manage water supply and demand. The government, working with Ofwat and water companies, needs to ensure the capacity of the water supply system in England is increased to boost the country's resilience to drought whilst also managing demand and reducing leakage. This can be achieved through: delivering a national water transfer network and additional water supply (for example reservoirs or water re use) by the 2030s; and halving leakage by 2050, together with greater smart metering.

Choosing and designing infrastructure

For government and relevant industries to take decisive action on their infrastructure projects, they need to have confidence that their decision making is as good as possible. Long term decisions inevitably carry risk, but these risks need to be taken, and uncertainty managed as much as possible. Decision making can be improved through robust analysis of the performance of existing infrastructure and recognising the value of good design in infrastructure.

Not everything can be reduced to numbers, but there should be an effective methodology to measure the quality of the UK's current infrastructure to reliably inform assessments of future needs. The assessment of the potential value of new projects could be more effective if there were better data on how past projects have performed. All government departments and agencies should therefore collect and publish costs and benefits estimates and outturns for major infrastructure projects. This would lead to increased scrutiny of costs and benefits estimates, improving quality.

Good design can save money, reduce risks, add value, deliver more projects on time and create infrastructure that looks good and works well for everyone. All nationally significant infrastructure projects should have a board level design champion, and use a design panel to maximise the value provided by the infrastructure. The Commission, advised by a national infrastructure design group, will publish a set of design principles to inform this.

Funding and financing

While the Commission's recommendations comprise an ambitious programme of investment, this is not an unaffordable wish list. A crucial factor in the development of this Assessment has been the fiscal remit set by government. This provides a long term funding guideline for public investment in infrastructure of 1.0 to 1.2 per cent of GDP, including existing government funding commitments such as HS2.

Where infrastructure is funded by the private sector, and the costs of any recommendations will ultimately be met directly by consumers, the Commission has also provided a transparent assessment of the overall impact on bills. Where recommendations have net costs, the Commission believes that these are manageable and good value relative to the benefits the infrastructure provides.

The recommendations in this Assessment, and the implications for public expenditure and for bills, reflect the judgement of the Commission. In reaching its conclusions, the Commission has drawn on a wide range of evidence. Uncertainty is inevitable given the timescales for infrastructure investment, and so the Commission has also sought to understand how robust its decisions are to uncertainty, seeking solutions that will stand the test of time.

The recommendations are an affordable and deliverable strategy to modernise and strengthen the UK's infrastructure networks. Nevertheless, it is important that these recommendations are paid for at least cost. Part of this comes from improvements in design and delivery. Part comes from ensuring that infrastructure is financed in the best way possible.

These recommendations will require a combination of public and private financing. Financing itself is not in short supply. However, state financing institutions can help to encourage private investment and catalyse activity in new markets. The European Investment Bank does some of this, but there is a risk that access may be lost following the UK's exit from the EU. A UK infrastructure finance institution, focussed on specific objectives, should be established if access to the European Investment Bank ceases after the UK exits the EU.

There is also a need for a better understanding of the costs and benefits of private financing and traditional procurement in the delivery of publicly funded infrastructure. The Commission has developed an analytical framework to be used in the evaluation of the costs and benefits of financing options for new and existing projects, which will enable greater certainty about the costs and benefits of the use of private financing for public sector projects.

Over the Assessment's timeframe, changes to the way road users pay to use roads are inevitable. In particular, fuel duty revenues will continue to decline with the impending shift to electric vehicles. This presents a huge opportunity to design a system that improves on current road taxation by being fairer, more sustainable, more effective at reducing the negative impacts of driving, and attracting greater public support. For years, experts have proposed road pricing, only for it to be opposed by the public. The Commission intends to engage stakeholders and the

public on this topic to identify a new approach that works for the future of transport. Reforming how road use is paid for has been discussed for decades, but the issue is becoming more and more pressing and cannot be avoided forever.

Local funding mechanisms can help to ensure that local infrastructure is funded in a way that is fair, efficient and sufficient to meet local needs. The current system for gathering contributions from developers is complex, but raises more revenue than previous attempts. But the system could be improved still further. More funding mechanisms should also be made available to Local Authorities to enable them to capture a greater share of the uplift in land value that can occur with infrastructure investment. This should include making it easier to raise business rate supplements for up to one third of scheme costs, and giving local authorities powers to levy zonal precepts on council tax where public investments in infrastructure drive up surrounding property values.

Next steps

The Commission has outlined an ambitious set of recommendations. As the first Assessment, it could never solve everything. The Commission has therefore focused on key priorities to equip the UK with the infrastructure it needs. These recommendations will enable the UK to have a thriving digital economy, a low cost, low carbon energy and waste network, clean air, successful cities, and resilience to extreme weather. But the Commission cannot achieve this alone. Government, regulators, industry, citizens and others will all need to contribute to making this vision a reality. Over the coming months, the Commission will work to build consensus around its recommendations.

Infrastructure delivery 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 the responsibility of the Infrastructure and Projects Authority which advises on infrastructure delivery. The UK's exit from the EU will impact the UK's skills base and supply chain. There should be a strategic approach to manage this.

As its initial next step, the government has committed to lay the Assessment before Parliament, and to respond to the Assessment within six months (with a final deadline of a year). Its response will set out which recommendations it has agreed to, any further work required to take forward the recommendations, and alternative proposals for any recommendations it has not agreed.

The Commission will monitor progress in delivering government endorsed recommendations, and will report on this in its Annual Monitoring Reports.

The second Assessment, expected around 2023, will build on the recommendations in this report, as well as covering new ground.

Northern Ireland, Scotland and Wales

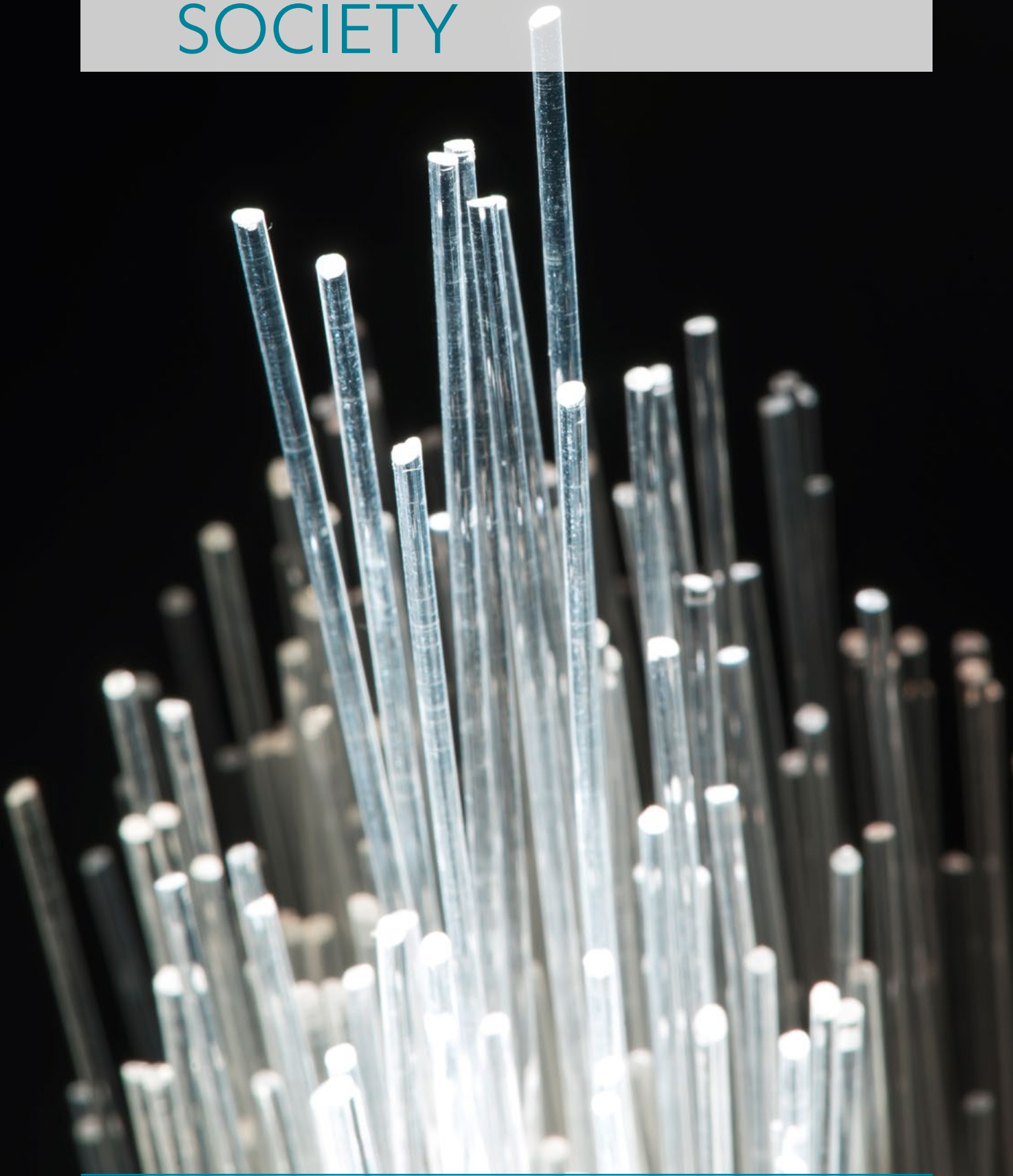
The Commission's remit covers six infrastructure sectors. As summarised in the table below, in four of six sectors covered by the Commission, there is substantial devolution to the devolved governments. Only energy in Great Britain and digital communications in the UK do not entail significant devolution.

The Commission's role is to advise the UK government. But the Commission works with both the UK government and the devolved administrations where responsibilities interact.

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

Table 1: Devolved administration responsibilities, by infrastructure sector

1. BUILDING A DIGITAL SOCIETY



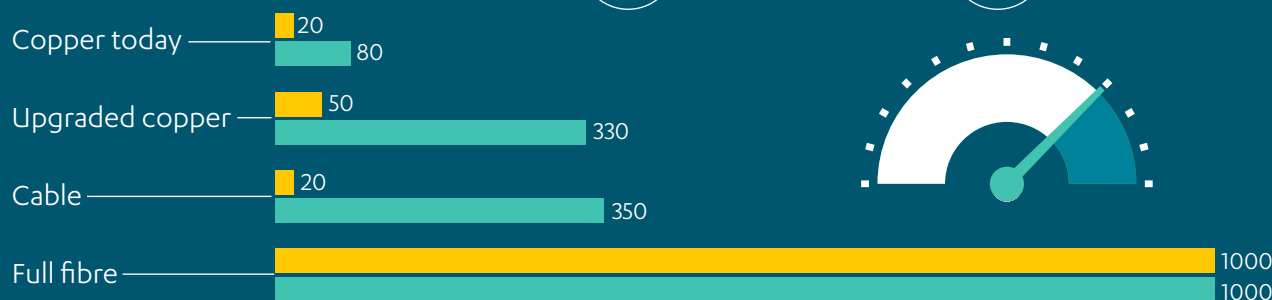
A FULL FIBRE FUTURE

Digital services are increasingly important for growth, infrastructure, and quality of life.

The superfast broadband programme is coming to an end and full fibre is the next step

Faster:

offering as much as 1,000 mbps



Upload speeds (mbps)



Download speeds (mbps)



More reliable:

fibre has 5 times fewer faults than copper connections



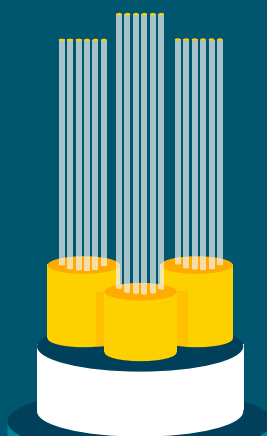
Cheaper to run:

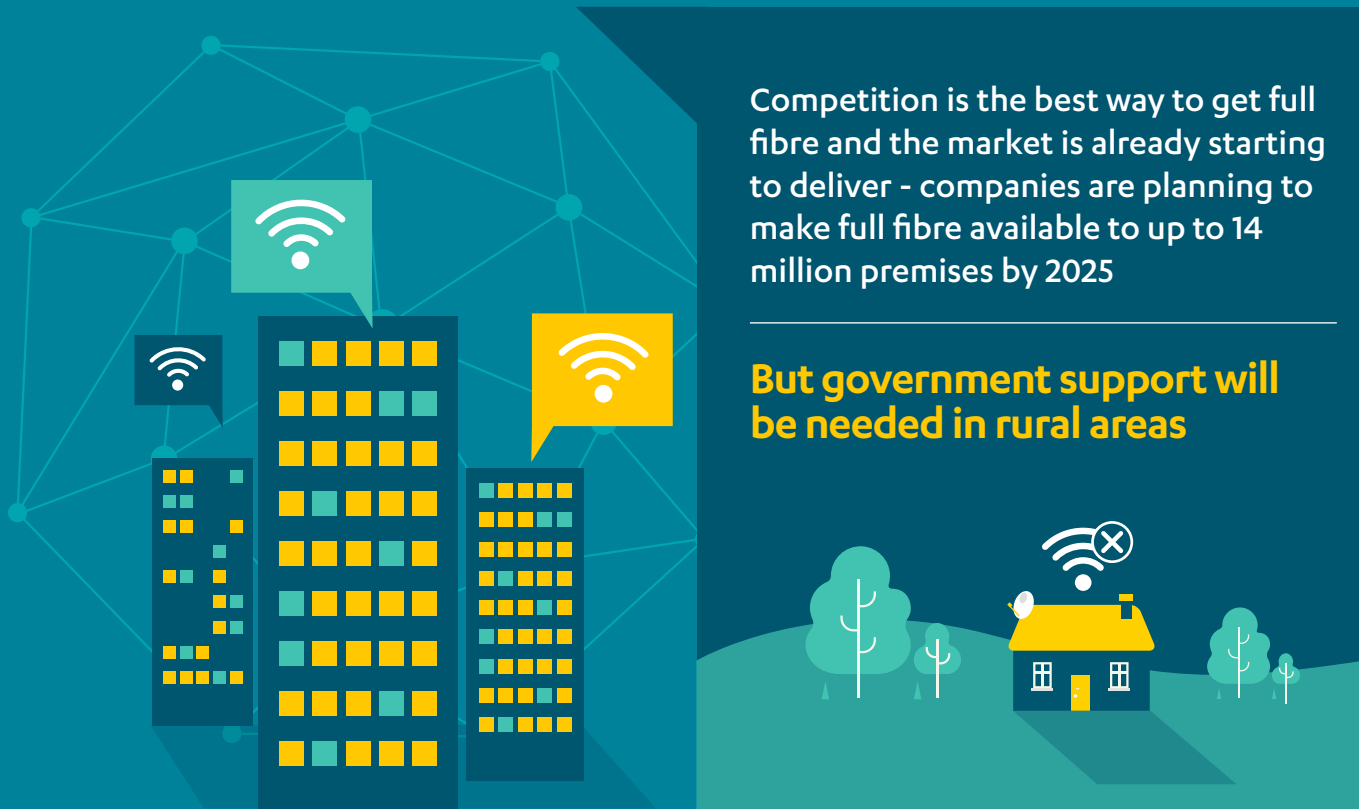
Fibre would save up to £5bn in operating costs over 30 years

The benefits will take time, as full fibre speeds are not yet needed, but delivery will take 10-20 years

Investment must start now

to avoid being left behind





Competition is the best way to get full fibre and the market is already starting to deliver - companies are planning to make full fibre available to up to 14 million premises by 2025

But government support will be needed in rural areas

THE COMMISSION RECOMMENDS:



A government strategy to deliver nationwide full fibre by 2033



Ofcom should promote network competition to drive the commercial roll-out of full fibre



Government support in rural areas starting by 2020



Measures aimed at cutting the costs of delivery



Allow for copper switch off by 2025

Sources: DCMS, Ofcom, Prism and Tactis, Frontier Economics

Digital connectivity is now an essential utility, as central to the UK's society and economy as electricity or water supply. Demand for data, and therefore the speed, reliability and capacity of broadband connections, is growing rapidly. Demand is likely to continue to increase as businesses, homes and infrastructure become smarter. So it is important that quality broadband is available throughout the country. Full fibre can provide this for the future.

The UK already has a strong digital economy underpinned by an extensive superfast broadband network.¹ There is room for improvement on mobile coverage and rural connectivity but, in general, the UK's digital connectivity meets the needs of today's consumers.² The UK compares well internationally for superfast broadband availability, but trails behind other countries such as Spain and Sweden for full fibre availability.³

The UK must now prepare for the future. The superfast broadband programme is coming to an end, with 98 per cent of UK premises on track to receive superfast broadband.⁴ A guaranteed minimum broadband service will be available to remaining premises by 2020 but provides only a basic service for today's needs.⁵

The Commission's judgement is that a national full fibre rollout programme should be put in place. This will provide fast, reliable broadband, improve connectivity in rural areas, and support 4G and 5G mobile coverage. However, it will take at least a decade to build.⁶

The successful delivery of full fibre will require:

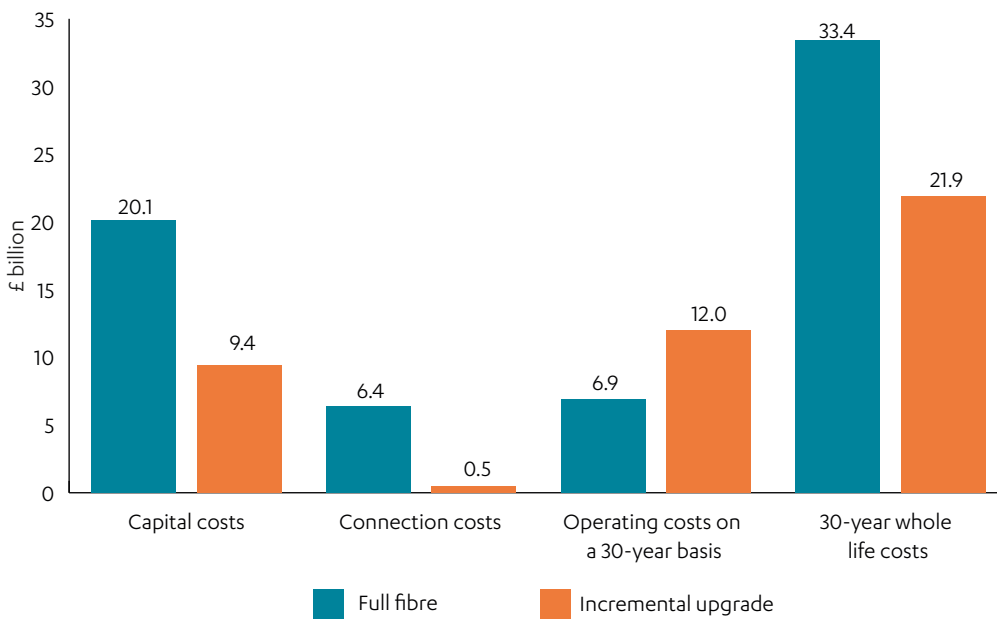
- a nationwide plan to deliver full fibre to all businesses and homes by 2033, with approaches tailored to the needs of different areas
- making the most of fibre deployment to support improved mobile coverage
- allowing for copper switch-off
- tackling the barriers that delay deployment and increase costs.

The Commission has previously examined the infrastructure needed to support 5G mobile in its report *Connected Future*⁷ and the Assessment does not re-examine this. The Commission is also carrying out a review of economic regulation, which will report in spring 2019.

Full fibre for the future

The UK faces a choice between continuing to upgrade the existing copper network, or replacing what is left of it with fibre optics. Full fibre, a connection without any copper, is the best available broadband technology on the horizon. It can provide consistent, gigabit speeds, which are less affected by rain and flooding, uses less energy, costs less to maintain and has no long term foreseeable capacity constraints.^{8,9,10,11} Nationwide full fibre would also provide the foundation for 5G mobile connectivity and could improve 4G coverage in harder to reach places.¹²

Choosing to make this investment is not a risk-free decision. In countries with widespread full fibre, take-up of higher bandwidth services is often low.¹³ Analysis produced for the Commission estimates that, over a 30 year period, building and maintaining a full fibre network would cost £33.4 billion.¹⁴ This is estimated to be approximately £11.5 billion more than incrementally upgrading the existing infrastructure.¹⁵ But a further incremental upgrade now may still require full fibre in the long term. Figure 1.1 shows the breakdown of costs.



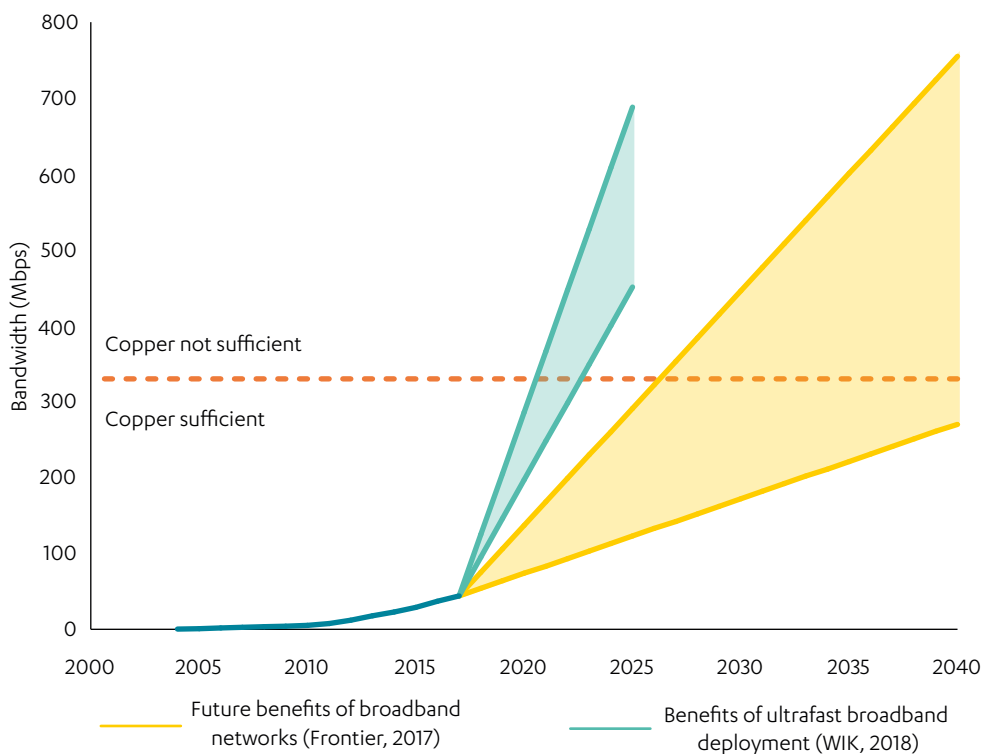
Note: present value in 2020

Figure 1.1: Estimated costs of deploying full fibre versus upgrading the existing copper/cable infrastructure¹⁶

The two alternatives to fibre are G.fast (a copper based technology), and cable (which uses shielding to reduce the electromagnetic interference that affects copper). G.fast might be an appropriate interim solution in some areas, but it is ultimately subject to many of the same limitations as copper. Unlike fibre, speeds on copper lines drop significantly over longer distances.¹⁷ Existing cable networks can be upgraded to compete more effectively with fibre over the long term.¹⁸ But Virgin Media, the UK's main cable provider, is increasingly rolling out fibre as it expands its network into new areas, partly because deploying and maintaining

new cable is more expensive than full fibre.¹⁹ Full fibre also has the potential to deliver much higher upload and download speeds.²⁰

Total data demand, based on the time spent on the internet, has risen drastically over the last few years.²¹ This is because people are online for more of the day and because the amount of data used at any one time is increasing, requiring higher bandwidth. Figure 1.2 compares projections of bandwidth demand, produced for the Commission and for Ofcom, the regulator, and the level at which a copper network becomes insufficient to meet demand. It is not clear when, or if, bandwidth demand will outstrip the capacity of the existing copper network. But it is possible that bandwidth demand could exceed the capabilities of a copper network within the 10-20 year horizon required to roll out a full fibre network.



Note: the dotted line is the theoretical maximum 'up to speed' on a copper upgrade.

Figure 1.2: Historic average UK broadband bandwidth and forecasted future bandwidth demand²²

However, despite the possibility that demand does not materialise, the Commission's judgement is that investment in full fibre is a risk worth taking. Past investments in digital infrastructure have supported significant economic growth. The rollout of broadband infrastructure in OECD countries from 1997 to 2007 increased annual per capita growth by 0.9 to 1.5 percentage points for a 10 percentage point increase in broadband penetration.²³

Potential drivers of future bandwidth demand

Demand increases to meet supply: History shows that as consumers' bandwidth increases, sites and applications adapt to make use of faster speeds. Video is the main driver of bandwidth demand. When BBC iPlayer launched in 2007 it required 0.5 megabits per second (Mbps) to watch programmes on demand.²⁴ Today, the minimum is the same, but iPlayer now offers a range of more sophisticated services that require much faster speeds, including 20 Mbps for Ultra HD programmes such as Blue Planet, and 36 Mbps for live events such as the World Cup.²⁵

Virtual reality: If the use of virtual (and/or augmented) reality increases for entertainment, simulations, or communication, this will require better, faster broadband connections.²⁶

Internet of things: Innovations in the network of infrastructure and appliances with digital connections will continue to increase the amount of data being transferred regularly through both the broadband and mobile networks.²⁷

Connected and autonomous vehicles: Connected vehicles are expected to transmit large amounts of data at high speeds to other connected vehicles and/or road infrastructure. This is likely to require reliable 5G connectivity on roads, which will need to be underpinned by fibre.²⁸

Furthermore, a full fibre network still provides several benefits relative to a copper network upgrade. These include operational savings, which would start being realised straight away and could amount to £5.1 billion between 2020 and 2050 (see figure 1.1). Full fibre suffers five times fewer faults than copper-based networks.²⁹ While not large enough to justify the investment in itself, these savings will continue beyond this timeframe.

A long term strategy for nationwide full fibre

Network operators are beginning to build new full fibre networks across the UK. However, only 4 per cent of UK premises have access to full fibre.³⁰

Delivering a new national full fibre infrastructure network will take at least a decade.³¹ Other estimates suggest the programme could be closer to 20 years.³² If the UK wants to avoid the risk of not having the infrastructure needed to support an increasing demand for data in the future, it will need to start investing soon, even if this is ahead of demand at present.

Transitioning to full fibre from copper is a substantial infrastructure upgrade, and it will be difficult for the market to deliver in the absence of a clear government strategy. Commercial investors will need clarity on government's decision to back full fibre to give them the confidence to invest.

Government must therefore define and deliver the country's full fibre broadband strategy. It should be responsible for the plan, and ensure that Ofcom has the necessary powers to implement and deliver it.

A nationwide strategy

Recent announcements by network operators already total 14 million premises expected to receive a full fibre connection by 2025,³³ but in reality this number will be lower as the networks will overlap. Therefore, while some areas will receive multiple full fibre networks on a commercial basis, many homes and businesses, particularly in rural areas, will not receive full fibre at all. The government has set a target date of 2033 for national coverage, but should now set out a clear strategy to achieve this, giving commercial investors the confidence they need.

A nationwide broadband plan must reflect the differing economics of delivering full fibre in different areas of the country. Government should promote competition in areas where it is commercially viable for multiple network operators to build and operate full fibre networks. However, some geographic areas are not commercially viable at all, and in others there is only likely to be a commercial case for one network (for example smaller towns and villages). A key part of government's plan must be to ensure that the places that would not otherwise receive full fibre get the connectivity they need.

Incentivising competition

Competing fibre networks should be encouraged wherever they are feasible. Without infrastructure competition, the existing provider has poor incentives to build new fibre networks, as this undermines its existing copper based services. New entrants do not have existing customers to lose, so they have greater incentives to build. Competition will force the incumbent to build new networks commercially and at a competitive price.³⁴

Infrastructure competition has been shown to drive investment in both new and existing broadband networks.^{35,36} It has been a key driver of widespread fibre rollout in South Korea and Japan, which have over 95 per cent full fibre availability.³⁷ There is a strong correlation between cable coverage and full fibre availability internationally.³⁸

The UK should therefore stick to a competitive model for commercial investors to deliver full fibre. This will require significant financing and it is essential that investors have confidence that if their business plans are successful, they will be able to make a fair return without the government reneging after the fact. The market must have the freedom to set the price for new services, subject, as now, to regulation of the basic service level. Within a competitive model consumers will have a choice of whether to pay any premium for full fibre. The market will drive full fibre deployment, and government should not intervene by restricting overbuild of new or existing networks, unless it constitutes anticompetitive behaviour.

This requires:

- a clear commitment from government and Ofcom to promote a competitive market wherever possible, with a stable regulatory regime

- a commitment to deregulate in geographic areas where competition is effective
- a commitment to ensuring telecoms providers can make a 'fair bet' for the risks they are taking in building new infrastructure, recognising the long term benefits of the infrastructure
- Ofcom continuing to ensure all providers can access Openreach's ducts and poles on a fair and efficient basis.³⁹

Reaching rural and remote areas

The Commission has concluded that nowhere should miss out on the benefits of full fibre. The Commission's social research found that 86 per cent of people agreed that all parts of the UK should have equal access to broadband.⁴⁰ In the past, the UK had the ambition and foresight to connect the whole country to electricity, water and transport networks. The benefits today are obvious. The same ambition is needed now for digital infrastructure.

The capacity constraint of the existing copper network is a particularly critical issue for rural areas with long copper lines. The performance of copper is severely affected by distance, and cannot be upgraded without replacing large parts with fibre, effectively rendering full fibre as the only viable infrastructure upgrade option for most rural areas.⁴¹ In the most remote areas, alternative technologies such as the use of mobile connectivity, fixed wireless or satellite might be more cost effective. Full fibre could also help to improve mobile coverage in hard to reach areas. 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.

Without full fibre, rural areas and some deprived communities where full fibre may not be commercially viable will risk falling behind. But everyone stands to gain from ubiquitous connectivity if it enables public services to use digital technology to become more efficient. For example, some health services are already moving online, which can provide better access to specialist services, reduce the need for patients to sit in waiting rooms where they risk further infection, and reduce costs for the NHS.⁴² Savings from online provision in rural areas are likely to be particularly large, where the costs of providing traditional services are higher in sparsely populated areas.

The Commission recommends a taxpayer-subsidised infrastructure delivery scheme to uncommercial areas, along the lines of the successful Broadband Delivery UK programme, which directly subsidised up to 50 per cent of the capital expenditure for installing superfast broadband in rural areas. A taxpayer subsidy can take advantage of competitive dynamics, with different companies bidding for tenders. In the short term, this can have positive implications for how quickly and cheaply the infrastructure is deployed. In the longer term, it also enables the costs and performance of subsidised delivery in one region to be measured against others.

Unlike the 'Broadband Delivery UK' programme, government should focus initially on the areas least likely to receive full fibre broadband commercially, and which are also most likely to experience unreliable broadband through long distances of copper cables. Communities within these areas should be eligible to get their full fibre sooner if they volunteer to help build their network at community level, as for example Broadband for the Rural North have done.⁴³

However, a reasonable cost threshold will be necessary: the most expensive premises can cost above £45,000.⁴⁴ This threshold should be high enough for the programme to cover the vast majority of premises. The few premises which are above the cost threshold should be able to use the subsidy to fund their own solution. The guaranteed minimum broadband service will act as a safety net.⁴⁵

Completing a nationwide rollout

In some areas of the country, only one fibre operator is commercially viable. It is uncertain whether fibre operators will rush to invest with the aim of becoming the monopoly provider or choose to avoid areas that cannot support multiple networks. In these areas, there is a choice between a targeted solution or relying on the combination of competition and eventual direct government support where the private sector doesn't deliver.

A targeted solution might meet the particular challenge, but would require the government to identify and define the boundaries of these areas upfront. This would rely upon uncertain and evolving assumptions. Changes in the cost of deployment and consumer demand could extend the area where competition is commercially viable, rendering any targeted solution out of date and potentially costly.

Given the pace of innovation in the industry, the potential for significant changes in consumer demand, and the long timescales over which any targeted solution would have to operate, the Commission believes that the boundaries should be allowed to reveal themselves over time. Providing government support for the hardest to reach areas first will allow the market to drive investment in the first instance. The part-subsidy scheme can then be extended in phases to areas that remain unserved, meeting market driven rollout 'in the middle'. If this results in support for provision in areas that are commercially viable, but for only one provider, the taxpayer contribution can be reinvested or refunded through clawback mechanisms.

Improving mobile connectivity

The Commission was asked in March 2016 to advise government on the steps the UK should take to become a world leader in the deployment of 5G mobile networks, and take early advantage of the applications 5G 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 that government ensures services are available

wherever people live, work and travel, and that the UK's roads, railways and city centres are ready for 5G.

The government and Ofcom have made some progress; the Department for Digital, Culture, Media and Sport has bolstered its telecoms capabilities and Ofcom has improved its coverage metrics to reflect actual user experience. Ofcom is also currently consulting on new coverage obligations, tied to the 700 MHz spectrum auction, to improve geographic coverage, particularly in rural areas.⁴⁶ However, government has made particularly poor progress on road and rail connectivity. It must accelerate its work to ensure 5G-ready infrastructure is available across the UK's motorways and major rail lines by 2025 at the latest.

The Assessment does not reopen the Commission's earlier mobile recommendations. The focus of the Assessment has been on fibre deployment for both fixed and mobile connectivity. Fibre is the necessary underpinning infrastructure for mobile connectivity. Full fibre policies have the potential to improve 4G coverage in hard to reach towns, villages and hamlets. It could also help deliver 5G further, more quickly and cheaply.

Mobile coverage is particularly poor in rural areas; 15 per cent of rural geographic areas cannot receive 4G coverage by any operator, compared to less than 1 per cent of urban areas. The Church of England recently agreed to using its church spires to improve mobile coverage. Two thirds of Anglican churches are in rural areas, situated in the heart of villages with tall spires, ideal for mobile cells. A full fibre connection to the highest point in a local village, whether or not that is the church, could allow mobile cells to be easily installed, improving connectivity in that local area.

Looking ahead, there is an option to preempt where 5G cells might need fibre. Subsidised full fibre rollout could include these locations. This includes lampposts and public buildings. Lampposts could be ideal sites for 5G cells, as well as WiFi and 4G cells today. They have access to power, are high up and evenly spaced out. But they do not automatically have fibre and will not receive it without coordination.

5G is a certain part of the future but what the 5G network will look like is uncertain. It is therefore a gamble to modify full fibre deployment based on any current 5G assumptions. Further evidence is needed to decide whether 5G obligations should be included with full fibre subsidies. The onus should be on wireless infrastructure operators to supply evidence and recommendations to the government.

Allowing for copper switch-off

Copper switch-off should be a key part of the long term national full fibre plan. Running a copper network adjacent to a fibre network will add significantly to overall costs. Switching off the copper network is ultimately a commercial decision for Openreach, the existing operator, but does require some government intervention to allow them to make the decision.

The transition plan will need to include protection for potentially vulnerable consumers. Some consumers will not want fibre but will receive it anyway. Openreach should not be able to charge customers extra that had no need for the upgrade.

Removing policy barriers

Tackling the barriers that delay deployment and increase costs must be an integral part of the UK's national full fibre broadband plan. Government has set up a Barriers Busting Task Force. This is a good first step and should continue to be prioritised. The Commission has identified four key objectives.

Give digital infrastructure operators the same rights as utilities: The process for obtaining rights of way on private land, known as 'wayleaves', should be simplified and standardised, through a notification regime similar to those used for other utilities. All new developments should have full fibre and telecoms duct capacity from the outset, as for other utilities such as electricity and water.

Prioritise digital connectivity at a local level: As recommended in *Connected Future*, local government should designate an individual 'digital champion' with responsibility for engaging with telecoms providers. The digital champion in each local planning authority should be responsible for coordinating and facilitating digital infrastructure deployment in their area, acting as the single point of contact for all telecoms providers, and assisting them in delivering better connectivity for the local area. Digital champions should prioritise:

- reforming and streamlining the process around permissions for street works, reducing the variability across the country and removing inefficient delays
- improving the accessibility of their publicly owned assets, making it easier and cheaper for operators to deploy digital infrastructure in the local area.

Increase infrastructure sharing to push full fibre rollout further: Access to Openreach's ducts and poles allows alternative operators to deploy fibre more quickly and cheaply. They no longer need to dig their own trenches, which can make up to 60 per cent of total deployment costs.⁴⁷ This increases the areas of the country where full fibre can be rolled out commercially. The success of this policy should be monitored by levels of usage to ensure that Openreach's infrastructure is accessible in practice. There may not be benefits from duplicating in-building fibre connections, which are costly and disruptive to install. Countries such as Spain, Portugal and France mandate that in-building fibre is accessible to all operators.⁴⁸ Ofcom should consider whether such policies should be applied in the UK.

Making use of other existing infrastructure can also reduce deployment costs. For example, using aerial fibre along existing electricity poles may push some

premises below a reasonable cost threshold in rural areas. Infrastructure re-use should therefore be explored before premises are ruled out for being too costly.

Ensuring planning is fit for 5G deployment. The next generation of mobile will require a large number of small cells raising planning issues such as access to street furniture (eg lampposts). This will require collaboration between network operators and local authorities to ensure planning and other permissions are handled swiftly and in a coordinated way. The UK will not get the mobile infrastructure it needs if each individual cell requires separate planning permission. Planning policy, legislation for code powers, and guidelines for deployment at street level will need to be addressed before dense site deployment can take place. The Commission made recommendations on 5G in *Connected Future*.⁴⁹

The Commission recommends that government should set out a nationwide full fibre connectivity plan by spring 2019, including proposals for connecting rural and remote communities. This should ensure that full fibre connectivity is available to 15 million homes and businesses by 2025, 25 million by 2030 with full coverage by 2033. To achieve these targets:

- Ofcom should promote network competition to drive the commercial rollout of full fibre, by deregulating where competition is effective and guaranteeing a fair bet on risky investments before regulating any uncompetitive areas.
- Government should part subsidise rollout to rural and remote communities, beginning by 2020, starting with the hardest to reach areas and community self-build.
- Government and Ofcom should allow for copper switch-off by 2025.
- Government and Ofcom should take action to cut the cost of full fibre deployment including:
 - Government should ensure the processes for obtaining wayleaves and connecting new builds are the same for digital infrastructure as other utilities by 2019.
 - Local government should designate ‘digital champions’ to improve telecoms processes such as street work permissions and access to publicly owned assets.
 - Ofcom should monitor the accessibility of Openreach’s duct and pole infrastructure by levels of usage.

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2. LOW COST, LOW CARBON



LOW CARBON INFRASTRUCTURE AT NO EXTRA COST

Reducing emissions has often appeared costly and difficult, but this is no longer the case, if the right decisions are taken now

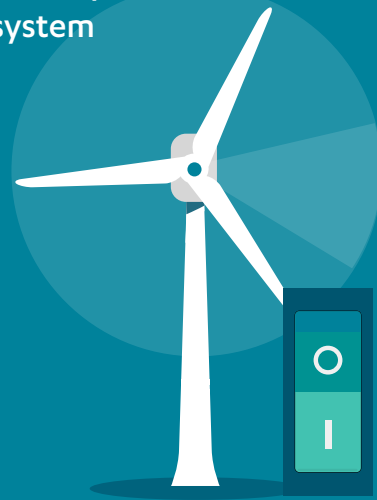
Today, consumers pay an average of

£1,850

per year for electricity, heating, hot water and petrol or diesel



The same services could be delivered at the same cost in 2050 by a low carbon energy system



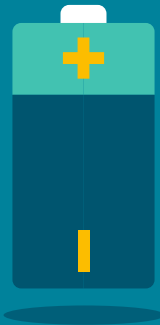
The Commission estimates that an electricity system powered mainly by renewables would cost no more than relying on new nuclear power plants

Renewables need more flexibility to balance variations in weather, but are cheaper to build

Sources of flexibility are getting cheaper: battery prices have fallen

80%

since 2010



Burning natural gas for heating and hot water is not a long-term option:

22%

of UK's greenhouse gas emissions come from heating



THE COMMISSION RECOMMENDS:



At least 50% renewable electricity generation by 2030



No more than 1 more contract for new nuclear before 2025



Pilots to test hydrogen and heat pumps as low carbon heating options



Buildings which require less energy to heat

INCINERATING LESS, RECYCLING MORE

England needs to do as well as Wales – a world leader – at recycling

PEOPLE ARE WILLING TO DO THEIR BIT:

50%

would pay £30 a year for more recyclable packaging



79%

of people would be willing to separate their food waste

BUT THEY FIND THE CURRENT SYSTEM TOO COMPLICATED

Higher recycling, especially of plastics, could:



Save £6.2 billion from 2020 to 2050



Avoid the need to build 20 additional incinerators



Reduce greenhouse gas emissions

THE COMMISSION RECOMMENDS:



Recycling targets: 65% of all waste, 75% of plastic packaging, by 2030



Clearer labelling: recyclable or not recyclable



Restricting use of hard to recycle plastics, by 2025



Separate food waste collection, by 2025

The UK can have low cost, low carbon electricity, heat and waste. Ten years ago, it seemed almost impossible for the UK to transition to being powered mainly by renewable energy sources such as solar and wind power in an affordable and secure way. Now the same focus needs to be applied to deliver a value for money approach to reducing emissions from heat. Low cost, low carbon energy and waste systems are now possible, and should be delivered.

The UK is legally bound to reduce its greenhouse gas emissions by at least 80 per cent from 1990 levels by 2050. Today, around 70 per cent of emissions come from electricity, buildings, travel and waste.¹

Reducing emissions has often appeared costly and difficult, but this is no longer the case. Today consumers pay an average of £1,850 per year for the energy they use, including electricity, transport fuel, and fuel and equipment for heating and hot water.² The Commission's analysis shows that the same services could be delivered at the same cost (in today's prices) in 2050 by a low carbon energy system.³ But this will only be possible if the right decisions are taken now.

The Commission's modelling has shown that delivering a low carbon electricity system for 2050 powered mainly by renewables is a low cost option, cost comparable to building further nuclear power plants after Hinkley Point C. The Commission's modelling also shows that continuing to use fossil fuels with the addition of carbon capture and storage is unlikely to form part of a cost competitive generation mix.

Reducing the waste sent to energy from waste plants (incinerators) by recycling more plastic and converting more food waste into biogas can also help reduce overall emissions. But even with emissions almost eliminated from power generation and waste, the UK cannot achieve its emissions targets without transitioning away from using natural gas, a fossil fuel, for heating. The UK must now address this problem. In the short term, improving the energy efficiency of the UK's buildings will reduce demand for heat and mitigate some of the emissions. In the longer term, it will also reduce the costs associated with delivering low carbon heat infrastructure.

The successful delivery of a low cost, low carbon energy and waste system requires:

- a flexible electricity system and new generation, primarily through renewables
- determining the best way to deliver low carbon heat in the UK

- buildings which require less energy to heat
- encouraging more recycling, and less waste incineration.

A lower cost, low carbon energy system

Reducing carbon dioxide emissions from the power sector no longer needs to be considered expensive. The Commission's analysis suggests that, across electricity, heat and transport, switching to and using low carbon alternatives does not need to lead to higher costs for consumers in the long term. The need to replace fossil fuels is driving a shift away from technologies, many over 100 years old, that society has become locked into, but which are now beginning to be replaced by more efficient alternatives.

Today, consumers pay an average of £1,850 per year for the energy they use, including electricity, transport fuel, and fuel and equipment for heating and hot water.⁴ The Commission's analysis shows that the same services could be delivered at the same cost (in today's prices) in 2050 by a low carbon energy system.⁵

Heating is currently predominantly fuelled by natural gas, a fossil fuel. Transitioning to a low carbon alternative (the two main options are electrified heat, using heat pumps; and hydrogen fuelled heat) will add to household bills. But these extra costs can be outweighed by switching to use electricity rather than petrol or diesel for transport. The cost of supplying low carbon electricity is falling.

These estimates are inevitably uncertain. Savings will only be possible if the right decisions are taken. In particular, these estimates assume investment in cost-effective energy efficiency measures.

The Commission's cost estimates:

- assume a typical household, consuming the same quantities of energy services today and in 2050
- include the costs of electric vehicle charging infrastructure and home heating appliances (boilers, heat pumps) as well as the costs of energy and fuel
- exclude potential savings on the cost of cars and car maintenance from the switch to electric vehicles, and the one-off costs of energy efficiency measures
- exclude tax – there would be further savings for households from today's tax system (since petrol and diesel are heavily taxed) but these savings would have to be made up elsewhere by the Exchequer
- average the projected costs of predominantly hydrogen and predominantly heat pump scenarios for low carbon heat

- assume continued technology development for existing technologies (eg battery storage) but do not take into account potential new technologies.

Full details are set out in the technical annex: *Energy and fuel bills today and in 2050*.

Renewables have become cost competitive

It is now possible to conceive of a low cost electricity system that is principally powered by renewable energy sources. The Commission's analysis has shown that the estimated average cost of the electricity system as a whole between 2030 and 2050 is broadly comparable between investing heavily in nuclear power stations or investing heavily in renewables (there is very little prospect of new nuclear, beyond Hinkley Point C, coming on system before 2030). Figure 2.1 shows slightly lower average costs for a scenario with 90 per cent renewable and less than 10 per cent nuclear compared to a scenario with 40 per cent renewable and around 40 per cent nuclear, regardless of whether heat is predominantly electrified using heat pumps or provided through low carbon hydrogen in the future. The higher cost of managing the variable nature of many renewables ('balancing') is offset by the lower capital cost, which translates into lower costs in the wholesale market.

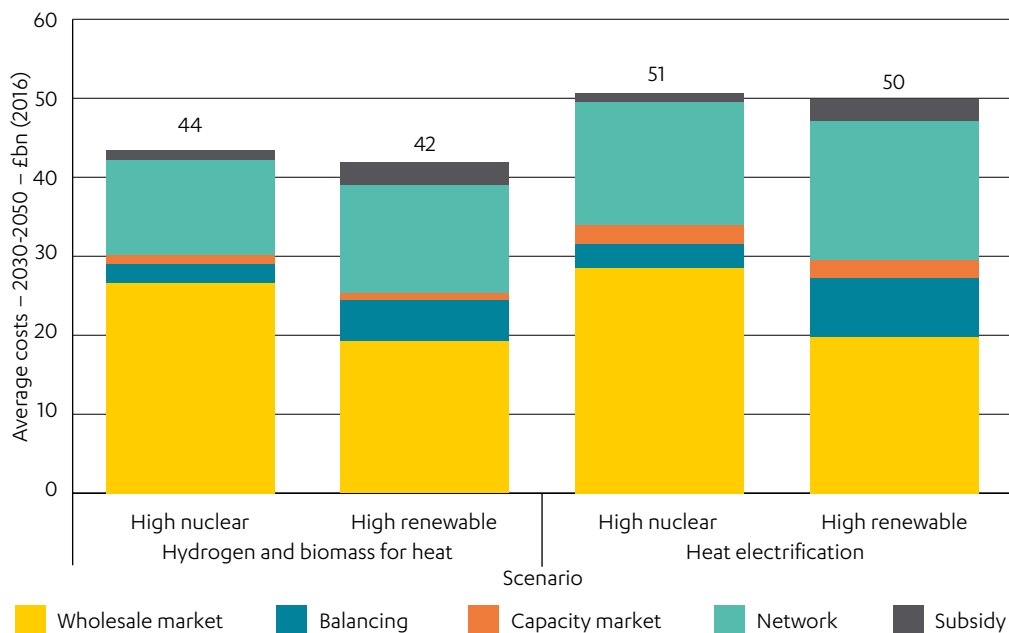


Figure 2.1: Average cost of the electricity system per year for different proportions of renewables/nuclear and heat decarbonisation pathways⁶

Estimates over such a long time period, and with considerable technological change, are inevitably uncertain. Specific figures should not be given undue weight. However, the broad conclusion of the analysis implies that an electricity system with no further nuclear plants after Hinkley Point C is likely to be cost comparable with a system which accommodates a new fleet of nuclear reactors.

These estimates assume continued reductions in the costs of renewable technologies. However, in recent years actual cost reductions have exceeded expected reductions.⁷ If the trend were to continue, and reductions were to exceed those assumed here, then the case for renewables would be stronger still. Further reductions could arise, for example, from new, cost effective, technologies for energy storage: the modelling does not assume untried technologies.

Historical evidence suggests it is much less likely that nuclear costs will fall. Figure 2.2 shows the construction costs of nuclear power stations in various countries, by construction start date. This shows no discernible trend in construction costs over time. This is true even for countries, such as France, that have built fleets of similarly designed reactors. The issue of long term disposal for nuclear waste is also still unresolved in the UK.

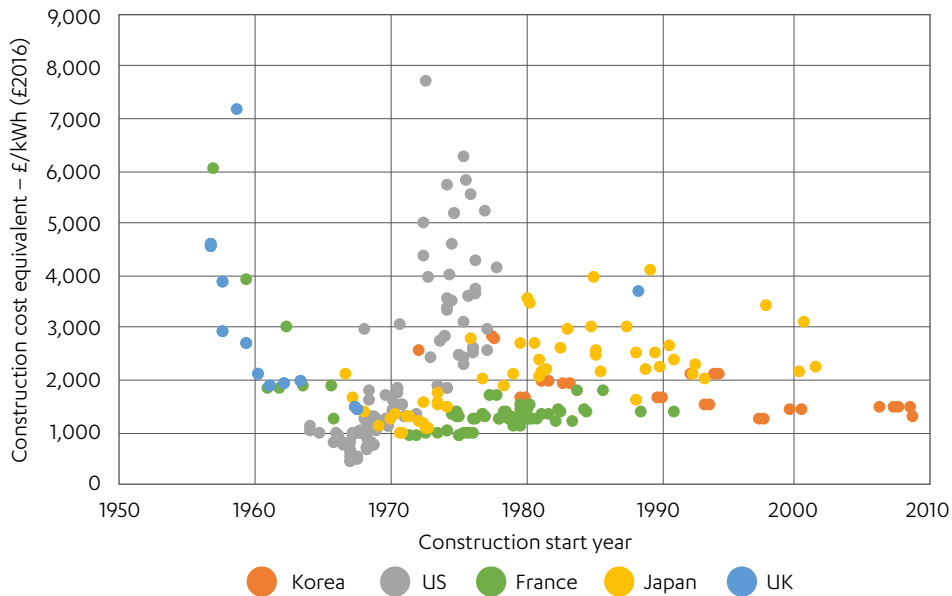


Figure 2.2: Construction costs of nuclear power stations over time⁸

Paying for nuclear and carbon capture and storage

New nuclear power plants and carbon capture and storage infrastructure will not be built by the private sector without some form of government support. This can come in a variety of forms. Expenditure will be treated as either 'on' or 'off' the public balance sheet (the account of government's assets and liabilities) depending on an assessment by the Office for National Statistics of where the risks and rewards sit.

Off public balance sheet deals, such as the package for Hinkley Point C, leave risks predominantly with the private sector. The National Audit Office found that this procurement model for Hinkley Point C did not provide best value for money for consumers.⁹ It is also questionable whether a further deal on this basis could be agreed, given the scale of risk that the private sector is required to hold.

A commonly discussed alternative 'regulated asset base' model, as used for the Thames Tideway Tunnel, could also be classified as off the government balance sheet. In this case, however, consumers hold both some risks and some elements of financing. The Thames Tideway model requires consumers to pay for infrastructure in advance. This makes projects appear cheaper as consumers are effectively financing the projects at zero interest. At least some of the risk associated with construction costs also sit with consumers, a further hidden cost, since consumers are not paid to hold these risks in the way investors would be.

Funding nuclear power stations or carbon capture and storage on the public balance sheet represents a transfer of risk from the private to the public sector. Cost overruns would ultimately be paid for by taxpayers, at least in part. These risks are not reflected in the government's cost of borrowing, since it is taxpayers, rather than the holders of debt, who bear the risk. But this does not mean the risk, and its associated costs, have been avoided. The apparently lower financing costs represent a transfer, rather than a reduction, in risk.

On balance sheet options would need to compete with alternative uses of the government's balance sheet. Chapter 7 sets out the Commission's choices within the resources government have set out (the 'fiscal remit'). The Commission have not assumed any on balance sheet nuclear power stations in making these choices.

It is not clear what the best model for either type of project would be, since this would depend on the commercial terms available and where risk can best be managed. Past experience of on balance sheet nuclear construction in the UK has been mixed. There is limited experience of using the regulated asset base model for anything as complex and risky as nuclear. However, any assessment needs to recognise the full costs and risks. It should not be distorted by hidden costs or used to present costs as artificially lower.

Given the balance of cost and risk, a renewables based system looks like a safer bet at present than constructing multiple new nuclear power plants. But a large amount of uncertainty does remain. No country has yet built an electricity system with very high levels of variable renewables. It will be important to develop a better understanding of how such a system performs under adverse weather conditions, particularly given that climate change itself makes such conditions

harder to predict. The risk is that the extra services required to accommodate large amounts of renewables may be harder, or more expensive, to source than envisaged. But given that some technologies which provide flexibility are still fairly immature, the costs could also be lower than the analysis suggests.

Given these uncertainties, the Commission is recommending a ‘one by one’ approach to new nuclear plants, as opposed to the current government policy to develop a large fleet. This is preferable to a ‘stop start’ approach, in which the nuclear programme is cancelled only to be restarted at a later date. It will allow the UK to maintain, but not expand, a skills base and supply chain. This allows the UK to pursue a high renewables mix, which is most likely to be the preferred option, without closing off the nuclear alternative.

The Government should also seek to ensure continuity with current Euratom arrangements as the UK leaves the EU, to ensure that on 29 March 2019 the UK has the necessary measures in place for the nuclear industry to continue to operate.

A more flexible power system

Matching energy supply and demand means the electricity system needs ‘flexibility’, both within days and across seasons. This can be provided by a combination of flexible supply (energy that can be generated on demand); energy storage; and flexible demand (demand that can be moved to a time of day when there is more supply).

To date, carbon intensive fossil fuels have met some of this need by providing plenty of flexible supply. But as they come off the system in favour of (mostly variable) renewable energy, flexibility will need to be maintained in other ways. The Commission’s analysis takes into account the cost of providing additional flexibility, as well as wider system costs such as the transmission and distribution of electricity. More renewables do lead to more money being spent to match supply and demand: a system with 90 per cent renewables is estimated to cost up to £4.5 billion more per year to balance. But cheaper capital costs are estimated to offset this within the costs for the overall system.¹⁰

In all scenarios, extra flexibility, which includes technologies such as storage, interconnection and demand side response, is a low regrets investment which reduces estimated total energy system costs by between £1-7 billion per year on average between 2030 and 2050.¹¹ This finding echoes the conclusions of the Commission’s *Smart Power* report.¹² Extended periods of low sun and wind in the winter can be met by a range of flexible technologies or, in the extreme case, by using limited amounts of fossil fuels. These events are rare, so the impact on emissions would remain small.¹³

The Commission’s analysis demonstrates that a rapid uptake of electric vehicles in the 2020s (see Chapter 3) can not only be accommodated, but that the batteries in electric vehicles could be a valuable and low cost source of flexibility for the electricity system in future. Provided smart charging is implemented, electric

vehicles can provide demand when it is otherwise low and potentially return power, stored in car batteries, to the grid at peak times ('vehicle to grid').¹⁴

A level playing field for different renewables

The existing mechanism for supporting low carbon generation technologies is called 'Contracts for Difference'. To reduce generators' exposure to volatile wholesale electricity prices, Contracts for Difference require generators to sell energy to the market as usual, but contract government to pay generators any difference between the market price and a pre agreed 'strike price', which is usually valid for 15 years. At times of high market prices these payments reverse and the generator is required to pay government back the difference between the market price and strike price.¹⁵

The Commission favours the use of existing market mechanisms – Contracts for Difference and the capacity market – where possible, to avoid creating more uncertainty, but incremental improvements could be made. The Contracts for Difference mechanism can provide both certainty for generators and a subsidy (depending on the agreed 'strike price'). Low carbon generation technologies have so far not been cost competitive, bringing both of these into play.

Since the introduction of Contracts for Difference, there have been significant reductions in the costs of renewables to consumers, through the competitive allocation of support. For each Contracts for Difference auction, technologies at similar stages of development are grouped together in different 'pots'. Pot 1 was set up for 'established' technologies, including onshore wind and solar, and pot 2 (for 'less established' technologies) contains, amongst other technologies, offshore wind. Only one pot 1 auction has been run to date.

Revising the distribution of technologies between pots and reinstating a pipeline of pot 1 auctions would enable the lowest cost renewable generation mix to be brought forward in the 2020s. Onshore wind, which enjoys strong public support overall,¹⁶ but has been controversial in some communities, would still be subject to planning restrictions in England. Projects in Wales and Scotland would no longer be held back. Pot 2 auctions could be used to allocate small amounts of support to emerging technologies, especially where they are likely to be able to contribute to the reduction of system costs in future.

Low carbon generation technologies should benefit from the support from Contracts for Difference. However, as set out in the Commission's interim National Infrastructure Assessment, it is also important that generators are responsible for costs and benefits they impose on the system, such as those related to where they situate. Some sites impose costs, for example due to the need for new transmission infrastructure, or benefits, for example if local weather conditions complement those elsewhere.

Over time, the different costs and benefits of new generation should increasingly be reflected in the auction process, allowing the lowest cost system to be developed. However, calculating these impacts is very complex, and in practice

a mixture of pricing and other mechanisms will need to be used to ensure total system costs are reflected in the bid price. As the generation mix evolves, it will be essential that both technological and spatial diversity are maintained across the system. This may involve making use of administrative limits for each technology within auctions.

As the prices of low carbon technologies continue to fall, the need to subsidise low carbon generation through Contracts for Difference will reduce and, particularly in later years, the mechanism may require payments from generators. This could result in contracts that provide the certainty required for low cost investment, but which are low cost or cost neutral for consumers over their duration. This may be important, as no one knows what the electricity markets will look like in the long term, or what factors will drive the electricity price. However, contract lengths will also need to reflect the need to retain flexibility in the future development of the electricity market.

Tidal power

The Commission's analysis suggests that tidal lagoon power will remain an expensive technology in the future. The extra benefits which arise from its predictability are not enough to offset its higher capital costs.¹⁷ And it will never be a large-scale solution: an entire fleet of tidal lagoons would only meet up to 10 per cent of current electricity demand in the UK.¹⁸ This also limits the scope for cost reductions through the kinds of learning and scale economies that have been achieved with wind and solar power. Further details are set out in technical annex: *Tidal power*. Given the broad portfolio of readily available lower cost, low carbon technologies, special treatment for tidal lagoons in the form of bilaterally agreed contracts is not justified. However, tidal should be allowed to compete on an equal basis with other technologies for Contracts for Difference.

The near term: 2020 – 2030

Increasing population and electric vehicle uptake means that energy demand could increase by 9-26 per cent from today to 2030.¹⁹ And over this period, up to 40 GW of older power stations will come offline.²⁰ This creates a large opportunity to continue to reduce emissions from the electricity system throughout the 2020s without stranding assets.

New nuclear power stations are unlikely to be an additional source of electricity in the 2020s, with the possible exception of Hinkley Point C. Large scale projects have long construction timelines and often face delays. Smaller reactors are still at an early stage of development and their benefits remain speculative. It is estimated that the end-to-end deployment process will take 12-14 years for the first small modular reactor.²¹

Since a system with a high proportion of renewable generation looks cost effective in the long term, and adding more nuclear to the system in this timeframe is unlikely, it makes sense to continue to add more renewables to the system in the 2020s.

However, not all new sources of supply in the 2020s need be renewable. Interconnectors, of which there is a large pipeline of projects, are likely to become of increasing importance throughout this period, and the Government should ensure that the current pipeline is not affected by the UK's exit from the EU. It may also be cost-effective to deploy a limited amount of new gas power stations, provided they can be accommodated within the carbon budgets, and recognising that load factors are likely to be on a reducing path.²²

The Commission recommends that in order to keep the option of a highly renewable system in 2050 open, at least 50 per cent of generation (in TWh) should be renewable by 2030. This would be equivalent to between 12 and 19 GW of offshore wind being deployed, in addition to the current pipeline.²³ The Commission's analysis suggests that the budget of £557 million that the government has set aside for future Contracts for Difference auctions may be sufficient to achieve this, depending on the future wholesale price of electricity.²⁴ However, if interconnectors do not deliver expected benefits, up to 65 per cent of generation may need to be renewable to meet 2030 carbon targets.

The Commission recommends that government should set out a pipeline of pot 1 Contracts for Difference auctions, to deliver at least 50 per cent renewable generation by 2030, as part of the transition to a highly renewable generation mix. Government should:

- Move technologies that have recently become cost competitive, such as offshore wind, to pot 1 following the next Contracts for Difference auction in Spring 2019. Pot 1 should be used for the overwhelming majority of the increase in renewable capacity required.
- Publish indicative auction dates and budgets for the next decade by 2020.
- Over time take whole systems costs into account in Contracts for Difference auctions, as far as possible.
- Consider whether there is a case for a small-scale, pot 2 auction in the 2020s, if there are technologies which are serious contenders for future pot 1 auctions.
- Not agree support for more than one nuclear power station beyond Hinkley Point C, before 2025.

Carbon capture and storage

The Commission's analysis included carbon capture and storage (CCS) as a potential option for the electricity system. Carbon capture and storage would allow the continued use of fossil fuels. However, the Commission's analysis showed that it rarely appeared to be a cost effective option for reducing power sector emissions. In scenarios where small amounts were cost effective, this was in the 2040s. This finding held even when carbon dioxide transport and storage costs were assumed to be very low, indicating the outcome if carbon capture and storage had already been built for other purposes. This shows it does not make sense for electricity consumers to subsidise the development of carbon capture and storage, since it will not benefit them in future.

Generation scenario	Heat decarbonisation scenario	CCS cost assumption	Percentage of CCS in the 2050 generation mix
40% renewable	Hydrogen and biomass	Central	1%
		Low	5%
	Electrification	Central	4%
		Low	8%
90% renewable	Hydrogen and biomass	Central	0%
		Low	0%
	Electrification	Central	0%
		Low	0%

Figure 2.3: Percentage of generation from fossil fuelled power stations equipped with carbon capture and storage in 2050 under different scenarios for generation mix, heat decarbonisation pathways and carbon capture and storage costs

There are several other potential uses for carbon capture and storage, including the reduction of emissions from industrial processes and combining it with biomass combustion to create negative emissions. However, the most pressing reason to develop it at scale is likely to be for the manufacture of low carbon hydrogen. This will be required if the UK chooses to remove carbon emissions from heat through diluting or replacing natural gas with hydrogen, especially in the absence of a global hydrogen market. Removing and storing the carbon from natural gas as part of producing hydrogen is a simpler process than capturing it as it is burnt in a power station.²⁵

Informing future decisions on heat

Reducing emissions from heating in an affordable way is the next challenge. Currently 69 per cent of heat is produced through burning natural gas, a fossil fuel.²⁶ This must be radically reduced. Uncertainties around cost, technology, and consumer behaviour means that it is difficult to decide the cheapest way to replace natural gas to meet future Climate Change Act targets now. However, this uncertainty is not an excuse for inaction in the near term. Low carbon heat at lowest cost will benefit the environment and improve many people's lives.

There are two potential large scale solutions for low carbon heat, and a range of smaller solutions which may complement one of them. The first option is electrification, using heat pumps to increase the efficiency of using electricity for heating. Alternatively, hydrogen from a zero carbon source (which creates only water vapour when burnt) could be used as a direct replacement for natural gas, fuelling boilers and appliances.

Whilst there are incremental steps that can be taken to address some aspects of the challenge, an incremental approach on its own will not be enough. In the 2020s, decisions will be required on whether the gas network should be maintained and converted, or phased out.

The Commission's analysis shows that currently all routes to low carbon heat are more expensive than maintaining the status quo, although the cost of heating as a proportion of GDP in 2050 is estimated to reduce.²⁷ The impacts of this cost will also be offset by switching to cheaper forms of energy in other areas, particularly transport.²⁸ Central estimates indicate an average annual cost between now and 2050 of £13 – 16 billion above the current system cost of £24 billion.²⁹ These figures are highly uncertain. Finding ways to reduce both the uncertainty and magnitude of them must be a priority.

For government to make choices about the decarbonisation of heat in the 2020s, there needs to be a coherent programme to ensure that the evidence to do so is in place. This should include collaborating internationally on research and development, to give government the confidence to invest in the best solution when the time is right. The Commission plans to provide further advice to government on this issue in the next National Infrastructure Assessment, taking into account parallel strategies in Scotland and Wales.

The Commission recommends that government needs to make progress towards zero carbon heat:

- **Establishing the safety case for using hydrogen as a replacement for natural gas, followed by trialling hydrogen at community scale by 2021.**
- **Subject to the success of community trials, launching a trial to supply hydrogen to at least 10,000 homes by 2023, including hydrogen production with carbon capture and storage.**
- **By 2021, government should establish an up to date evidence base on the performance of heat pumps within the UK building stock and the scope for future reductions in the cost of installation.**

Buildings which require less energy to heat

Improving the insulation of buildings makes sense both now and in a low carbon future. The Commission's analysis suggests that there are over 21 million individual improvements to buildings in England that together could save billions of pounds. This includes insulating 10 million lofts, 6 million floors and almost

5 million walls. This is equivalent to 21,000 improvements being installed every week between now and 2035.³⁰ The current rate of progress is around 9,000 improvements installed per week.³¹

Delivering these improvements alone represents a major challenge. Driving widespread improvements in energy efficiency is notoriously difficult. Different interventions to stimulate uptake will be required across different segments of the building stock.

However, an even more ambitious approach may ultimately be required. The optimum level of energy efficiency is partly linked to the choice of heat technology: in particular, heat pumps work best in buildings with reasonably high insulation standards because they provide constant, but low temperature levels of heat.

A range of different initiatives will need to be trialled and fully evaluated, learning from international experience, and progress regularly reviewed. The government will need to prepare for the fact that it is likely that some future energy efficiency initiatives may fail. But this should not lead to a loss of momentum or enthusiasm for energy efficiency. Alongside this, innovation in energy efficiency products and processes should also continue to be supported, particularly for solid walls. An immediate priority is the social rented sector. Under any approach, government will inevitably bear most of the cost of improving energy efficiency either through direct grants, support to social landlords or rental payments via Housing Benefit. The Commission estimates that cost effective improvements to existing socially rented properties would cost £3.8 billion. A ten year programme would meet government's own stated ambition of ensuring social rented properties reach at least Energy Performance Certificate level C by 2030.³²

The Commission recommends that government should set a target for the rate of installations of energy efficiency measures in the building stock of 21,000 measures a week by 2020, maintained at this level until a decision on future heat infrastructure is taken. Policies to deliver this should include:

- Allocating £3.8 billion between now and 2030 to deliver energy efficiency improvements in social housing.
- Government continuing to trial innovative approaches for driving energy efficiency within the owner occupier market.
- Government setting out, by the end of 2018, how regulations in the private rented sector will be tightened and enforced over time.

Incinerating less, recycling more

Low cost, low carbon waste is also necessary and achievable in the near term. The Commission's remit on waste covers England only, where waste generation is expected to rise as the population grows. Energy from waste plants (incinerators) facilitated the move away from landfill, and make sense when the alternative is

energy from fossil fuels. They incinerate 'black bag' waste and other wastes that cannot be recycled, producing electricity and providing heat where there is a source of demand nearby.

However, lower cost, lower carbon options exist for some types of waste, in particular food waste and plastics. In these areas, England should not settle for the minimum standards set out in EU legislation but should seek to be amongst the best performers, learning from the example set by Wales.

Separating food waste

As an alternative to incineration, food waste can be treated in 'anaerobic digesters'. Anaerobic digesters break down biodegradable waste in the absence of oxygen, producing biogas and a low grade fertiliser ('digestate') at a fraction of the capital cost of incinerators.³³ In future, technologies such as pyrolysis or gasification, may also become available commercially.³⁴

Biogas can be used as a low carbon substitute for natural gas. It can also be converted to a range of biofuels, which may prove especially valuable in sectors where fossil fuels are hardest to replace, such as aviation. Besides treatment, there are benefits to collecting food waste separately, such as preventing the contamination of other recyclable materials.

Using anaerobic digestors requires the separate collection of food waste, which is typically collected weekly in household 'caddies' designed for the purpose. In 2014-15, only 26 per cent of English households had separate food collection.³⁵ The Commission's analysis shows universal food waste collection would avoid the need to build between 1 and 3 energy from waste plants between now and 2050. It would save up to £400m in capital costs and £1.1bn in operational costs for local authorities in total between 2020 and 2050.^{36 37} This includes the cost of weekly collections.

In the Commission's social research, 79 per cent of participants without caddies said they would be willing to use one.³⁸ A higher recycling rate more generally reduces the demand for residual waste infrastructure. By 2035, a 65 per cent recycling rate, with separate food waste collection, would mean that 7 million tonnes less residual capacity is needed, equivalent to 20 energy from waste facilities.³⁹

The Commission recommends that government should establish separate food waste collection for households and businesses (to enable production of biogas) by 2025.

Wales: a world leader in recycling

In 2008, Wales had a similar recycling rate to England (approximately 40 per cent). Today, Wales has the third highest municipal recycling rate in the world (64 per cent).⁴⁰

Wales achieved this through its 'towards zero waste' strategy. The strategy established ambitious recycling targets for local authorities, mandated the separate collection of food waste and provided a blueprint for standardised collection of other materials.⁴¹

To ensure local authorities had the capacity to deliver effective recycling collection systems, the Welsh Government provided £68 million in capital support for recycling infrastructure.⁴² Additionally, the ability to fine local authorities that missed their recycling targets was introduced.⁴³ In practice, only one local authority has been fined; all that missed the targets were referred to a support program. Communication campaigns were conducted to raise awareness of what could be recycled.

By becoming a leader in recycling, Wales saw the total cost of collection for local authorities fall. In the process, it avoided 105,000 tonnes of carbon dioxide emissions.

Reducing plastic waste

A more circular economy, with a higher recycling rate that keeps materials in use for longer, could save local authorities a total of £6.2bn between 2020 and 2050.⁴⁴ Targeting plastics is particularly important. Increasing the plastic recycling rate will also reduce emissions generated from burning plastics (effectively a fossil fuel) and reduce leachates that can contaminate local water systems when plastic is landfilled.

Despite this, the UK's plastic recycling rate is just 30 per cent.⁴⁵ This is due to both household behaviour, and product design. In England, 53 per cent of households throw away items that could be recycled.⁴⁶ This appears, at least in part, to be due to a lack of clarity on recycling; the Commission's social research suggests many people would like to recycle more but find it complex and confusing.^{47,48}

The first priority should be to reduce unnecessary packaging and other single use plastics. The government have launched a range of consultations in this area. It is important that these lead to action. Thereafter, it is important to target hard-to-recycle materials. The way packaging is designed can alter the cost and viability of recycling. To date, incentives in the waste system have been focused on weight. The government is currently reviewing this approach, as reductions in weight may have reached their limit. Setting incentives to improve product design could help reduce the cost of recycling.

Some materials are particularly problematic. PVC can compromise recycling of PET, which is otherwise widely recycled.⁴⁹ Polystyrene is almost never economical to recycle and particularly dangerous to marine life.⁵⁰ In the long run, these materials need to be replaced if packaging is to be sustainable. A clear timetable

by which these products would be phased out would allow industry to develop sustainable alternatives.

A package of measures to improve supply of recyclable material, standardise collection regimes and clarify labelling is needed to push recycling rates upwards. Government initiatives and incentives to target specific products such as the Deposit Return Scheme or recent proposals on packaging reform are important steps forward, but they need to work alongside ambitious headline targets.⁵¹

The Commission recommends that government should set a target for recycling 65 per cent of municipal waste and 75 per cent of plastic packaging by 2030. Government should set individual targets for all local authorities and provide financial support for transitional costs.

The government should establish:

- Clear two symbol labelling (recyclable or not recyclable) across the UK by 2022.
- A consistent national standard of recycling for households and businesses by 2025.
- Restrictions on the use of hard-to-recycle plastic packaging (PVC and polystyrene) by 2025.
- Incentives to reduce packaging and for product design that is more easily recyclable by 2022.
- A common data reporting framework for businesses handling commercial and industrial waste by the end of 2019, ideally through voluntary reporting but if necessary by legislation.

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3. REVOLUTIONISING ROAD TRANSPORT



GETTING READY FOR THE ROADS REVOLUTION

Vehicles of the future will be cheaper, cleaner, quieter and safer.

As prices fall and range increases, take up of electric vehicles could accelerate rapidly

ELECTRIC VEHICLES MEAN:

1 Cleaner air

vehicles contribute to 80% of air pollution breaches and 34% of greenhouse gas emissions

2 Lower costs

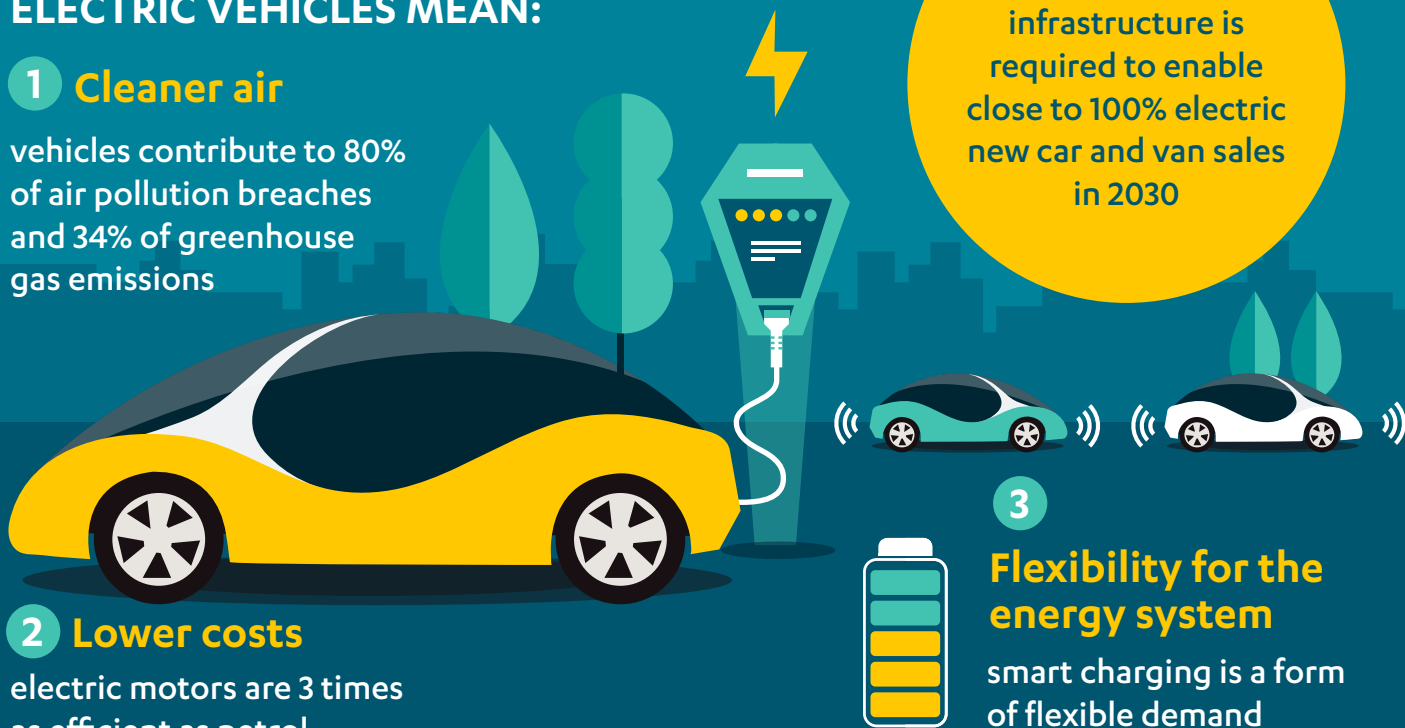
electric motors are 3 times as efficient as petrol

Charge point infrastructure is required to enable close to 100% electric new car and van sales in 2030

3

Flexibility for the energy system

smart charging is a form of flexible demand



CONNECTED, AUTONOMOUS VEHICLES WILL MEAN:



Safer roads

over 1,700 people are killed on the roads per year



Accessibility

more people can travel by car



Time freed up

driving takes an average of 140 hours per year

BUT ROADS WILL NEED TO CHANGE. SOME IDEAS ARE:

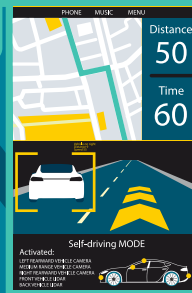
1 Connecting cars and traffic signals, instead of waiting at the lights

2 Flexible curbs changing use through the day, instead of yellow lines

3 Separate lanes, instead of mixing different types of vehicle

4 Variable speed limits, smoothing the flow of traffic

5 Automatic re-routing of journeys, instead of traffic jams



THE COMMISSION RECOMMENDS:



Making it easier to convert parking spaces and provide charge points on the street



Investing in the electricity network to achieve the benefits of electric vehicles



Future road and rail investment plans need to reflect the impact of connected and autonomous vehicles



Government support for rural charge points

Most journeys in the UK are made by road. After 100 years of incremental change, road transport is about to undergo a revolution. More electric cars and vans are being built and sold, and autonomous vehicles could soon be on the roads too. These vehicles will change the nature of the transport debate in the UK. Conventional vehicles bring pollution, noise and accidents; electric vehicles are cleaner and quieter, and connected and autonomous vehicles could make roads safer.

The UK is one of the top European countries in terms of electric vehicle sales,¹ and government already supports the move to electric vehicles.² But the UK should speed up its preparations; electric vehicles are fast becoming cheaper and better, and take up could accelerate. With the right conditions, including a national network of electric vehicle charge points, the UK could become a world leader in electric vehicles.

There is also potential for the UK to become a world leader in connected and autonomous vehicles. KPMG has ranked the UK fifth in the world in terms of readiness for connected and autonomous vehicles,³ and the UK is home to many companies developing this technology. The Commission has launched an innovation competition for ideas on how to deliver world-class roads ready for this revolution: 'Roads for the Future.'

Government must set a clear policy direction to encourage private sector investment in charging infrastructure for electric vehicles, and to prioritise research and innovation for connected and autonomous vehicles in the longer term. This will require:

- enabling electric vehicles to provide additional flexibility to the energy network
- enabling commercial charge point provision, with support in rural areas
- putting connected and autonomous vehicles at the heart of government planning
- preparing roads for connected and autonomous vehicles.

Electric vehicle uptake predictions

Electric cars and vans could become widespread ahead of most predictions, as prices continue to fall. Price falls are being driven by reductions in the cost of batteries, the most expensive component of an electric vehicle. Battery prices fell by 80 per cent between 2010 and 2016.⁴ This initially meant that the range of electric vehicles could be extended: some cars can now travel up to 300 miles

on a single charge.⁵ Once ranges are sufficient, further falls in battery prices can translate directly into falls in the prices of the vehicles.⁶ Upfront cost parity between electric and conventional vehicles is now expected by the mid-2020s.⁷ And as purchase prices become comparable, fully electric vehicles will look increasingly attractive, as they are cheaper to run.⁸ As these facts emerge, projections are evolving to reflect them: figure 3.1 shows how National Grid's electric vehicle uptake estimates have increased over the past three years.

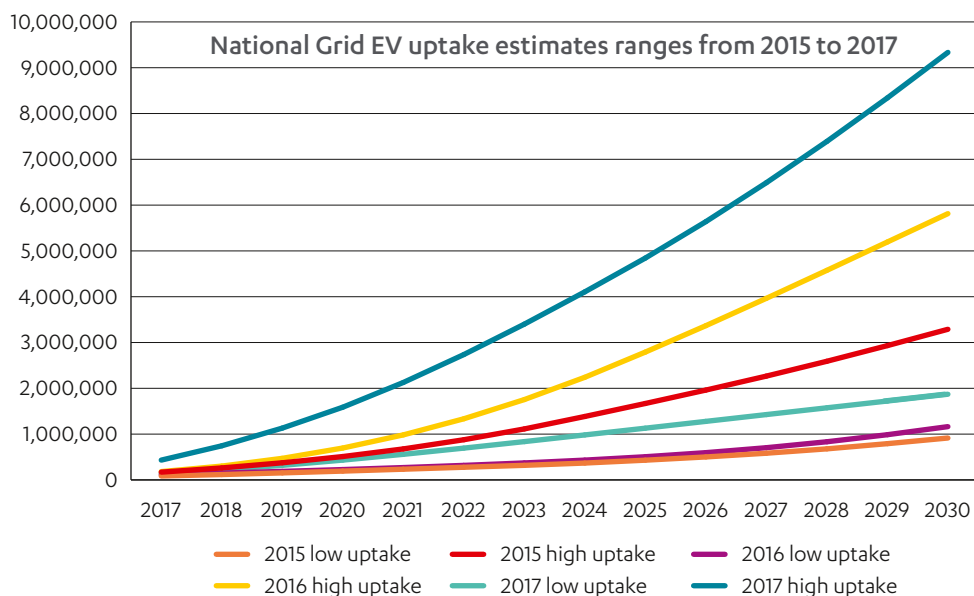


Figure 3.1: Range of battery electric and plug-in hybrid vehicle uptake estimates from National Grid's Future Energy Scenarios⁹

Given current industry momentum and falling costs, it looks like electric vehicles, rather than alternatives such as hydrogen, will capture the market for low emission cars and vans in the short to medium term. It is too early to know if electric vehicles are the future for larger vehicles. The Commission's study on the future of the freight system, due to report in Spring 2019, will consider how to reduce emissions and congestion from road freight.

New technologies typically follow an s-shaped diffusion curve, which starts to accelerate as uptake moves into the 'take-off' period. This can start when they have reached 5 per cent of their potential market.¹⁰ Figure 3.2 demonstrates how sales of videos declined as consumers switched to purchasing DVDs.

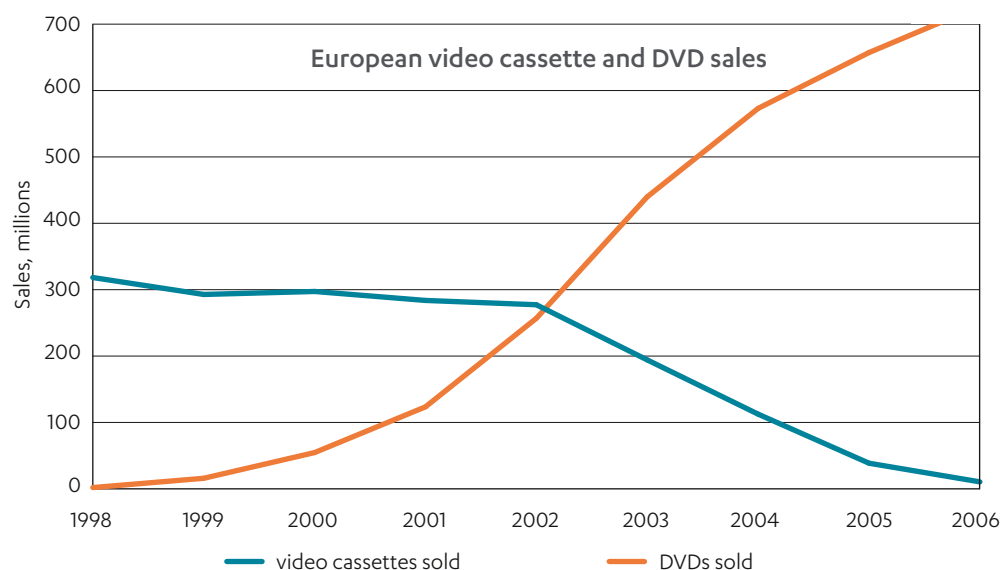


Figure 3.2: Sales of video cassettes and DVDs in Europe over time showing a typical s-shaped technology diffusion curve.¹¹

In 2017, electric and hybrid vehicles represented 1.8 per cent of all new registrations, up 27 per cent on the previous year.¹² Electric vehicles could therefore soon enter the ‘take-off’ stage in the UK. Some projections suggest that the UK could even see 100 per cent sales of electric vehicles by 2027, and 100 per cent stock by 2042.¹³

A 2016 Department for Transport survey showed concern about recharging was the most significant factor preventing consumers buying an electric vehicle (45 per cent), followed by the distance travelled by one charge (39 per cent).¹⁴ But aside from the need for a charging network, electric vehicles are likely to become increasingly attractive to consumers.

The uptake of electric vehicles will also depend on supply. Car manufacturers are beginning to ramp up electric vehicle production. Ford, the best selling car maker in the UK today, plans to have 40 fully electric or hybrid models in its global line-up by 2022, while Volkswagen, the second best selling car maker, is targeting 80 fully electric or hybrid models by 2025.¹⁵ At Nissan’s factory in Sunderland, electric vehicles roll off the same production line as petrol and diesel vehicles.

A rapid increase in uptake of electric vehicles is not certain. But it is certain that electric vehicles reduce the cost of driving, lower air pollution, and reduce emissions, in addition to supporting a highly renewable energy system. Therefore, government should encourage and facilitate the swiftest possible uptake of electric vehicles.

The Commission recommends that government, Ofgem and local authorities should enable the roll out of charging infrastructure sufficient to allow consumer demand to reach close to 100 per cent electric new car and van sales by 2030.

Electric vehicles and the energy system

The transition to electric vehicles will provide additional, low cost flexibility for the energy system.¹⁶ When electric vehicles are able to follow price signals and charge when demand is low ('smart' charging), they help to smooth out daily electricity demand. As shown in figure 3.3, the daily demand profile with electric vehicles leads to a lower proportion of capacity being spare throughout the day than without electric vehicles. This means that electricity networks are used more efficiently and reduces the need for other types of flexibility, such as small gas engines and batteries. Overall system costs are reduced.¹⁷ Furthermore, batteries considered at the end of their useful life in an electric vehicle may still retain up to 80 per cent of their original capacity.¹⁸ These batteries can provide a source of storage for the grid, reducing the need for further investment (and supporting the price of second-hand electric vehicles).

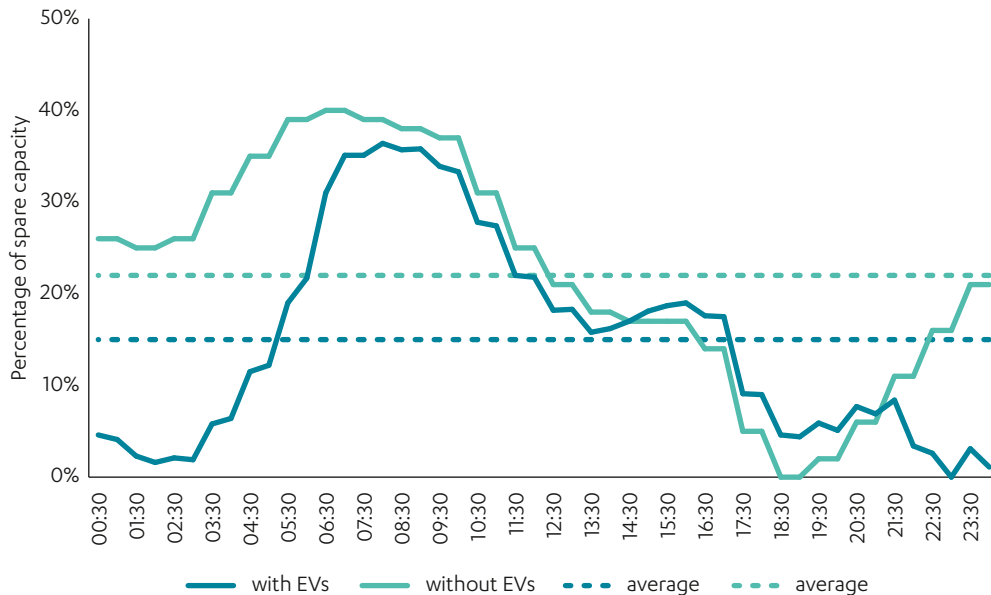


Figure 3.3: Percentage of spare generation capacity throughout the day with electric vehicles and without¹⁹

The Commission's analysis suggests that a 100 per cent uptake of electric cars and vans could increase total annual electricity demand by 26 per cent by 2050.²⁰ However, as electric engines are more efficient than petrol or diesel, each car would use less energy overall,²¹ and as electricity becomes increasingly low carbon, emissions would reduce. Chapter 2 sets out how the UK can achieve a low cost, low carbon energy system, whilst accommodating an increase in electric vehicles.

Smart charging

Smart charging is essential for reducing the overall cost of the energy system as the number of electric vehicles increases. Not putting in place the necessary policy incentives could increase power system costs by £2 billion per year on

average (2030-50), adding up to £30 per year on average to consumer bills (2030-50).²² This would primarily be driven by increased power prices and electricity network reinforcement costs.²³ Smart charging will be much cheaper for the consumer than on-demand, rapid charging, as prices are likely to be lower when there is less demand on the electricity network.

Smart charging should therefore be the default option for home charging. There is likely to be an overall consumer preference for smart and slow charging.²⁴ But this is not certain. It is slightly less convenient, and carries some risk if a car is needed for a long journey earlier than expected.

Regulation

The Office for Low Emission Vehicles works to support the early market, and the Automated and Electric Vehicles Bill, which is currently before Parliament, will give government powers to make regulations on the specification of charge points (including requiring all charge points to be smart and interoperable).²⁵

Given the importance of managing the interaction between charging and the energy system, it makes sense for Ofgem to take on the role of ensuring that there are arrangements to optimise use of chargers within the energy system. Ofgem should also consider whether there is a need to protect consumers from spikes in energy prices which could make rapid charging prohibitively expensive. Consumers should be able to refuel their car in an emergency without having to pay over the odds.

Government, industry and Ofgem should work together with the Office for Product Safety and Standards, the Institute of Engineering and Technology and the International Standards Organisation to ensure interoperability and the development of minimum standards for charge points.

The Commission recommends that Ofgem should take on the role of regulating the interaction between electric vehicle charge points and the electricity network immediately, ensuring that electric vehicle charging and vehicle to grid services contribute to the optimisation of the energy system. Government, industry and Ofgem should work together to set minimum standards for a network of interoperable, smart charge points.

A national network of charge points

Developing a nationwide, electric vehicle charging network offers the chance for the UK to get ahead. Too often in the past, short-term interests, a lack of coordination, and a tendency to endlessly debate difficult issues and delay difficult decisions have meant the UK has been slower to adopt new infrastructures than other countries. This time can be different.

Government funding is already available in the form of grants for home, workplace and on-street residential charge points. The Autumn Budget 2017 announced a new £400 million Charging Infrastructure Investment Fund,

including £200 million of investment from the private sector.²⁶ However, so far, no private sector partner has been procured.²⁷

Supporting charge point installation

Building electric vehicle charge points represents a big opportunity for the private sector. Demand for charge points is likely to grow.

Charge points are already being built across the country, growing from a total of 2,880 points in 2012 to 14,160 points in 2017.²⁸ Chargemaster plc plans to expand its POLAR charging network to 25,000 chargers by 2020.²⁹ A UK-based energy company, Pivot Power, is working with National Grid to build 45 new charging sites, each with up to 100 charge points, across the country, investing £1.6 billion.³⁰ And some petrol companies, such as Shell, have already begun installing electric vehicle charge points at their petrol forecourts.³¹

However, some potential charge point providers may be put off by the uncertain cost of connecting new charging infrastructure to the electricity network. New connections can trigger the need for network reinforcement, which the customer pays a proportion of as a connection charge.³² Ofgem aims to avoid imposing general charges for reinforcement costs, preferring to link them to a customer's own network usage. However, this needs to take into account the indirect system benefits from both rapid and smart chargers.

Rapid charge points are more likely to trigger reinforcements than slow, smart chargers. They do not directly benefit the energy system in the way that smart chargers do. However, at present rapid chargers also provide an indirect benefit to the electricity network by reducing range anxiety, incentivising uptake and therefore incentivising the spread of smart charging.

Passing reinforcement costs on to public charge point providers risks reducing the amount of charge points installed and ultimately ignores the benefits that network users gain from an electric vehicle fleet. Ofgem's recent process to look into whether extra investment was required concluded that given the current pace of change it was unlikely to be needed before 2023. However, this was only done in consultation with network owners and not with the aim of facilitating a rapid uptake of electric vehicles.³³

The Commission believes that this represents a missed opportunity. Ofgem should take a more proactive approach to preparing for future reinforcement needs for charging points; electricity networks should work with charge point providers to identify likely future reinforcements and invest ahead of time.

The Commission recommends that Ofgem should commission electricity network operators to work with charge point providers to identify potential anticipatory investments required to accommodate public charging infrastructure. Opportunities for investment within the current price control period should be identified by Summer 2019.

Furthermore, engagement with local authorities should not hold up the process of delivering charge points. Local authorities should work with commercial investors, make it easy for charge points to be built on their land, require charge points to be built as part of new developments, and free up parking spaces to be used for electric vehicle charging.

If travel patterns and car ownership models are fundamentally disrupted, vehicles may park and charge in different locations to today. But in the short term ensuring that charge points are installed and accessible for electric vehicles, and that this rollout is balanced against the needs of drivers of internal combustion engine vehicles, must be a priority.

On-street charge points for electric vehicles will be particularly important in dense urban areas where access to home off-street parking is limited, but these are the same areas where parking spaces in general will be at a premium. Local authorities will need to work with private sector providers and electricity network owners to identify where demand for charge points is likely to be highest, and ensure that there are sufficient parking spaces available for charge point installation as demand materialises.

The Commission recommends that government should place a requirement on local authorities to work with charge point providers to allocate 5 per cent of their parking spaces (including on-street) by 2020 and 20 per cent by 2025 which may be converted to electric vehicle charge points.

A visible core network

Although the majority of charge points are likely to be slow and smart, having a core network of visible, rapid chargers in place could significantly increase the pace of uptake. This network should provide both sufficient coverage, so that it is possible to find a charge point within a reasonable distance throughout most of the country, and enough power to fully recharge an electric vehicle within a reasonable timescale (for example within 1 hour). To enable close to 100 per cent of new car and van sales to be electric by 2030, the core network would need to be in place in the early 2020s to avoid inhibiting electric vehicle uptake.

The charge point network is often compared to the petrol station network but differs in two respects. Firstly, drivers of petrol and diesel vehicles do not suffer from range anxiety. Consumer confidence already exists in the petrol station network. Visible charge points in more places will combat this issue for potential electric vehicle drivers, and allay their concerns about being able to travel anywhere in the UK.

Secondly, the shape of the charging network is likely to be different to the petrol station network. Electric vehicle owners are more likely to recharge in towns and places where they can undertake other activities, than stop en-route. And petrol stations need to be accessible for fuel deliveries, which is not a consideration for charge points.

The pattern of private sector provision of charge points in the early stages of the electric vehicle market is likely to be similar to mobile and fixed broadband, where provision is strong in densely populated areas, but rural areas are initially underserved. Charge points in rural locations, which benefit users and society by contributing to a complete network providing coverage across the country, will not be as profitable as those in urban centres and main arterial routes, and many of the benefits from providing this network will go to electric vehicle purchasers and manufacturers rather than charge point providers. Therefore, commercial investors are less likely to build charge points in rural areas before electric vehicles become the mainstream choice.

This means there is a case for government support to build charge points in rural areas, to deliver a core national network in the short term, before relying entirely on the private sector to take forward the delivery of the network at scale as the pace of uptake increases. There are 332 'built-up' areas³⁴ in the UK with populations above 20,000. 187 of these are not served by a rapid charger. There are 145 built-up areas with populations above 50,000, 52 of which are not served by a rapid charger (shown in figure 3.4).

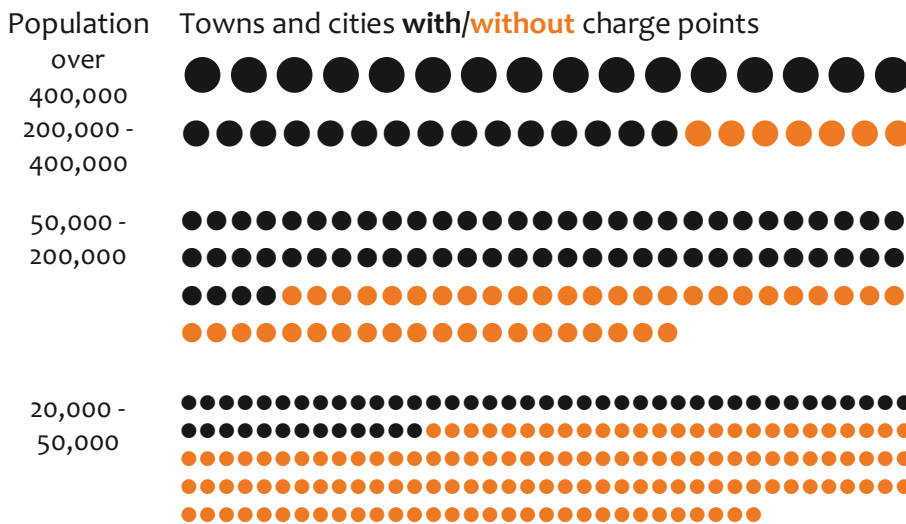


Figure 3.4: Proportion of built-up areas with at least one rapid charge point in June 2018 (by population)³⁵

At least one rapid charger in each of those places would represent a reasonable core network. The cost of installing a rapid charger is around £50,000, so the costs of installing chargers at 200 currently unserved locations would be around £10 million. Government does not need to directly own or operate these charge points.

The Commission recommends that government should subsidise, by 2022, the provision of rapid charge points in rural and remote areas, where the market will not deliver in the short term.

Preparing for connected and autonomous vehicles

Whilst electric vehicles represent a revolution in how vehicles are powered, the changes delivered by connected and autonomous vehicles could be more profound still. Connected and autonomous vehicles could have implications for the roads themselves, as well as the way people travel.

Connected vehicles can communicate with other vehicles or infrastructure on the road network, to assist with safer and better informed driving. Autonomous vehicles use a range of technologies to reduce the need for human involvement for navigating the road. These vehicles will have impacts on infrastructure design, capacity, demand, travel patterns, land use, and interactions between transport modes. All this is not yet understood. Government should start planning for these changes now.

Connected and autonomous vehicles will create new travel opportunities, free up time focused on driving, and could improve safety. They could also increase road capacity, enable higher speed limits and shorter journey times, encourage vehicle sharing, and release street space currently used for parking. Traffic lights and stop signs may become unnecessary. And the use of road space could be automatically and constantly changing according to need.

It is uncertain when fully autonomous vehicles will be a reality on the roads. Existing technology can already control the vehicle in a wide range of circumstances and is increasingly being deployed within cars on the market today.³⁶ Some estimates suggest that self-driving cars could be on the road by the 2020s,³⁷ although others predict this will take much longer. But despite uncertainty about the timetable and extent of change, it is no longer reasonable to assume existing patterns of road use will remain unchanged in future.

Government must first act decisively on the Commission's recommendation in *Connected Future* to roll out digital connectivity across the road network, starting with the strategic roads network by 2025.³⁸ Research indicates that improved connectivity, either 5G or in other forms, could enhance the road capacity benefits of automation by improving vehicle-to-vehicle and vehicle-to-infrastructure communication.³⁹

The potential impacts and benefits of connected and autonomous vehicles vary in different places and on the level of automation. For example, in urban areas, although careful management will be needed to avoid adding to congestion, automated on-demand public transport options could provide more convenience than buses or trams. Road transport is unlikely to supplant rail in its core markets: commuting into city centre (where physical space is a key limitation) and long distance city centre to city centre travel (where rail has a speed advantage). However, overall, connected and autonomous vehicles could have a significant positive impact on interurban connectivity.

Building the evidence base

Government has made a good start in positioning the UK as a centre of excellence for connected and autonomous vehicles. It has created a conducive environment for trialling, stimulated private sector innovation through various funding initiatives, and launched an extensive review of the regulatory environment. It has also begun to think strategically about the longer-term implications for transport through programmes such as the Industrial Strategy's Grand Challenge on the Future of Mobility.

These key steps are welcomed by the Commission. But the research programme now needs to evolve to ensure that connected and autonomous vehicles are central to transport policy and investment decision-making in future. In October 2017, government was funding at least 53 separate research projects, but the evidence on the impact of connected and autonomous vehicles has so far not been sufficient to influence the latest plans for road and rail (the second Road Investment Strategy and Network Rail's Control Period 6).

Planning for the 2025-2030 investment period, when highly autonomous vehicles are predicted by some to be on sale, will begin in the early 2020s. Government should aim for evidence on the impact of connected and autonomous vehicles to be sufficiently robust to start to factor in policy making for both planning processes.

The Commission recommends that government should address the implications of technological innovation in long term transport planning processes, including the next rail control period and road investment strategy.

A research framework

A research framework is required, focussing on four key areas: technology; legislation and regulation; people; and infrastructure. Extensive work is already being undertaken on the first two areas. Therefore, the priority for new research within the framework should be to focus on people and infrastructure, where research is less advanced. These two areas are fundamentally linked; how roads are changed to accommodate connected and autonomous vehicles will reflect and impact how, where, when and why people choose to use them and other forms of transport.

To assess people's behaviour patterns, trials will need to ensure that the information gathered is useful and reflects a wide cross-section of the public. While reliable forecasts of the take up and use of connected and autonomous vehicles are not likely to be developed until highly autonomous cars are on sale, government should focus on improving existing analytical tools to prepare as far as possible.

In terms of infrastructure, the government will ultimately need to determine changes in the way roads are planned, designed and operated to maximise the potential benefits of connected and autonomous vehicles. 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, to improve the outcome for road users. Despite the uncertainty, the process of thinking about how roads should adapt must start now, and take a flexible approach.

Roads for the future

The Commission launched 'Roads for the Future' in January 2018: an innovation competition on how roads should be designed, managed and used to maximise the benefits of connected and autonomous vehicles. An overall winner will be announced in September. The shortlisted entries are:

Smart signals, AECOM, York: Examining how smart signals could alert drivers and vehicles to the speed they should drive at so they arrive at the next set of traffic lights just as they turn green, cutting congestion and ending polluting 'stop-go' driving.

Active traffic management, Leeds City Council, Leeds: Examining how the data generated from digitally connected cars could be used to improve traffic light systems, allowing highway authorities to better manage traffic on their roads.

FlexKerbs, Arup, London: Looking at how kerbsides with fixed features such as double yellow lines, parking bays and bus stops could become more flexible, changing their use according to the time of day and levels of demand.

AI short term traffic prediction, Immense Simulations, Oxford: Using AI to help sat-nav systems to 'learn' better routes to improve the directions given, so that both driven and driverless cars could change course to avoid congestion.

Segregated connected and autonomous vehicle zones, City Science, Exeter: Examining how sections of existing roads could be dedicated to driverless cars, making it easier for highways authorities to manage risks, integrate connected and autonomous vehicles into the existing transport network, and encourage take-up.

To ensure that the framework is delivered and connected and autonomous vehicles are fully embedded in long-term transport planning processes the right structures need to be in place within government. At present, there is no single long-term home within government for research and analysis into future disruptive transport technologies.

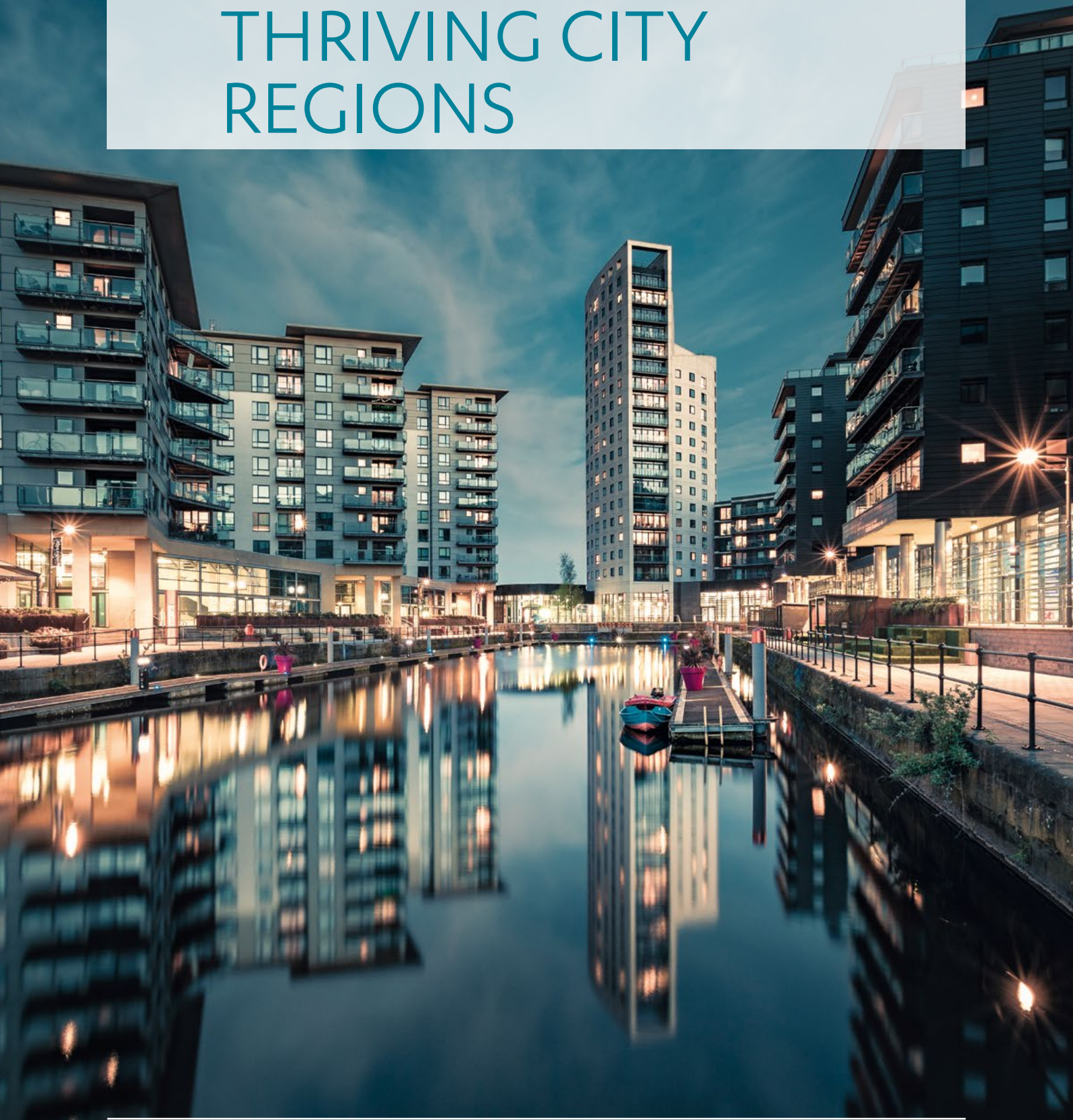
The Commission therefore believes that a new body should be created, subsuming the Centre for Connected and Autonomous Vehicles' current functions but with a wider policy remit and a more influential role in the Department for Transport's long-term transport planning processes. Amongst its responsibilities should be the Commission's proposed connected and autonomous vehicles framework. However, its core focus should be on ensuring that technological innovation is fully embedded in the planning processes for the third Road Investment Strategy and the next rail investment cycle, Control Period 7.

The Commission recommends that government should establish a centre for advanced transport technology in the Department for Transport to bring together work on technological innovation and ensure its implications are central to future investment proposals. This should include developing and overseeing the Commission's proposed connected and autonomous vehicles framework.

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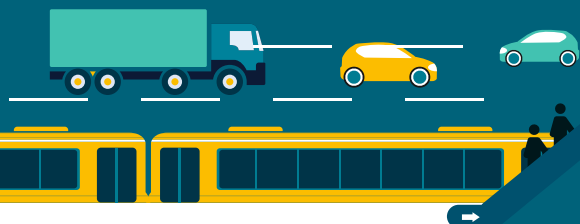
4. TRANSPORT AND HOUSING FOR THRIVING CITY REGIONS



CITIES ARE THE PRIORITY FOR FUTURE TRANSPORT INVESTMENT

Investing in urban transport can support productivity and quality of life

Intercity transport is getting the investment it needs



Highways England
4 billion
per year (2020-25)



Network Rail
6 billion
per year (2019-24)



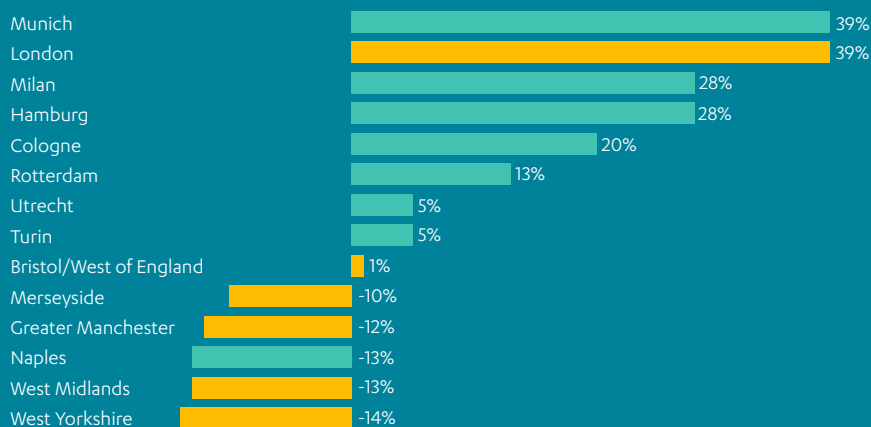
High Speed 2
4 billion
per year (2020-30)

BUT:

productivity is low in too many UK cities, unlike in Europe



GVA per capita relative to national average for relevant country



Transport networks are close to capacity in many UK cities

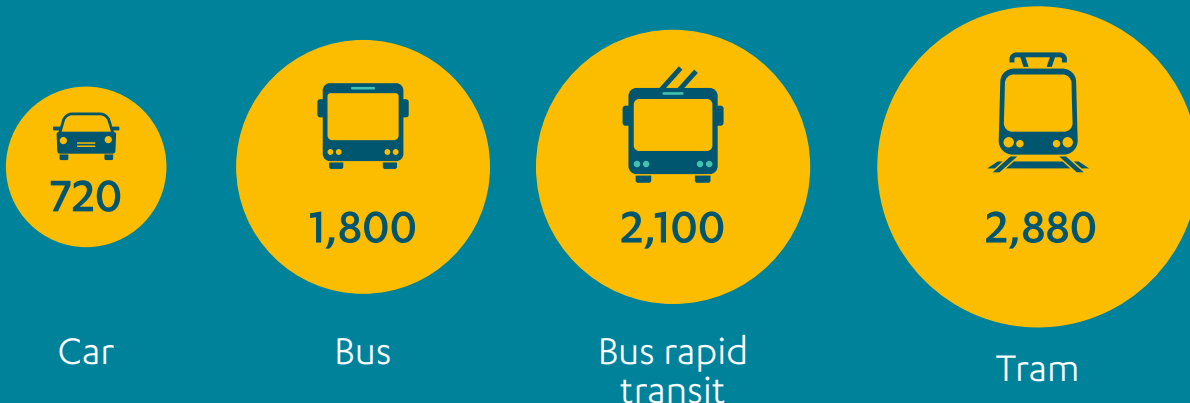


In cities, better cars can't solve the problem as there isn't enough space



Mass rapid transport is needed to increase accessibility

Typical maximum capacity per lane (inbound passengers per hour)



But transport alone isn't enough – cities need skills, green space, cultural and leisure activities



THE COMMISSION RECOMMENDS:



City-led plans for transport to connect housing and jobs



Devolved, long-term funding to give certainty to all cities



Major projects in the fastest growing, most congested cities

Sources: HM Treasury, Network Rail, Department for Transport, Eurostat, ONS, Steer Davies Gleave

Cities can and should be great places to live and work. But their increasing popularity means they are becoming full and congested, and this risks inhibiting growth and undermining quality of life. Space in cities should be used effectively, with room allocated for fast, frequent public transport systems, well connected and affordable housing, and pleasant public spaces. This will require a new approach to governance, strategy and funding for urban transport.

In recent years, government has prioritised major upgrades to transport between cities. The next wave of major upgrades should increase the focus on transport within cities. Infrastructure cannot drive growth alone; other factors, especially skills, are essential. But lack of infrastructure can inhibit growth.

The UK is unusual in that most large cities outside of the capital are less productive than the national average; cities such as Birmingham and Leeds should have the potential to be as successful as major cities elsewhere in Europe which boost their countries' productivity.¹ But this will require vision and planning. London, and to some extent Manchester, have benefitted from having a mandate to transform their cities' transport infrastructure. Other cities, large and small, need to be able to take the same approach.

Unlocking growth in cities requires:

- developing integrated strategies for housing, employment and transport, to allow cities to grow and people to live and work where they want
- devolving planning and funding for urban infrastructure to all cities
- prioritising major upgrades for cities with the most growth potential and capacity constraints
- £43 billion of additional investment in urban transport by 2040

Cities as social and economic hubs

Cities² are increasingly critical to the UK's economy and international competitiveness. The benefits of firms in knowledge based services clustering together in close proximity has made city centres attractive places for firms to locate, leading to a revival in many cities' fortunes.³ They are hubs for high value industries and employment; 60 per cent of all jobs and 71 per cent of knowledge intensive business service jobs are in cities.⁴ Supporting growth in city-regions is essential to providing balanced growth across the UK, as cities provide employment and a range of specialist services across a whole region.

Cities have also become more attractive places to live as they have attracted highly skilled workers and cultural and leisure amenities have grown.⁵ More than half of the UK's population live in cities, and as the UK economy has become more city focused, the popularity of cities has grown.⁶ London's population fell from 8.6 million in 1939 to 6.7 million in 1988, but this huge shift has since reversed, with London growing 30 per cent to 8.8 million in 2016.⁷ In other major cities, recovery started later, but in almost all cases population growth was stronger in the 2000s than in the 1990s and has accelerated in the current decade.⁸

Unlocking growth

Enabling people to work and live in or around cities is a key way in which infrastructure investment can support growth in every region. There are fast growing, infrastructure constrained cities spread across the regions of the UK,⁹ and addressing these constraints is the greatest opportunity for infrastructure to help each region to do better.

Most major UK cities lag behind national productivity levels. This contrasts with large cities in many other European countries, which add to their countries' productivity.¹⁰ Infrastructure cannot drive growth alone; other factors, especially skills, are essential. But lack of infrastructure can inhibit growth. To sustain future growth, transport policy must reflect the economic and structural changes that are shaping the UK's transport needs.

The priorities for transport investment should be growing and congested urban areas and their catchments, the key interurban corridors, and the key international gateways.¹¹ There has been welcome progress on the latter two areas in recent years. After years of delays, decisions on aviation capacity are being made following the report of the independent Airports Commission.¹² Investment in interurban corridors has increased sharply and is planned to increase further in the 2020s. Chapter 7 sets out the Commission's proposals for future investment in the strategic road and rail networks, with substantial continued investment. Chapter 3 sets out the need for future plans to respond to the opportunities from connected and autonomous vehicles.

However, investment in urban transport outside of London continues to lag behind.¹³ Urban transport networks underpin commuter journeys that create deep labour markets, and enable people to access cultural and leisure activities. Most urban journeys are short, relying predominantly on urban transport networks. The average trip length for people who live in cities and towns is under 10 miles, with fewer than 5 per cent of journeys over 25 miles.¹⁴ Rail journeys tend to be longer, but most start or end in cities.¹⁵ Infrastructure to support public transport in growing and congested cities offers some of the highest returns for transport investment.¹⁶

Investment in local and strategic transport

Intercity networks

Investment in national road and rail has been increasing, with further investment forthcoming to improve interurban transport. Highways England is proposing to spend more than £4 billion per year from 2020 to 2025; the government has committed around £6 billion per year for Network Rail between 2019 and 2024; in addition, HS2 is expected to cost around £4 billion per year on average throughout the 2020s.¹⁷ Northern Powerhouse Rail will deliver long overdue improvements in travel times between the major cities of the North of England.

Continued focus is needed to deliver these major commitments. Sub-national transport bodies will need to work with government on the development and delivery of these programmes and will play an important role in ensuring that they are integrated with regional and local networks.

Local road maintenance

In recent years, insufficient funding has led to poor conditions on local roads, affecting road users throughout the country. Six per cent of urban local A roads are considered to be in poor or very poor condition, and 3 per cent of rural A roads.¹⁸ This creates hazards for road users, and also increases the long term cost of maintenance. The economic case for maintenance is very strong, since inadequate upkeep creates a risk that roads may need to be closed for emergency repairs.¹⁹

The major funding decisions for transport in the first half of the 2020s – Road Investment Strategy 2 for Highways England, Control Period 6 for Network Rail and major projects such as HS2 – have already been made or are shortly to be decided. They therefore fall outside the scope of the Assessment, since the Commission’s remit states that the Commission “will not reopen decision making processes where programmes and work have been decided (or are due to be decided immediately after a [Commission] report is published)”.²⁰

It is for the Department for Transport to prioritise in the early 2020s between providing the funding needed to maintain the existing road network or to deliver the full programme of enhancements. In the later 2020s, the Commission believes that £500 million a year of funding should be made available for local highways authorities to address the local road maintenance backlog probably through to the early/mid 2030s.

The Commission recommends that government should make £500 million a year of funding available from 2025/26 to 2034/35 for local highways authorities to address the local road maintenance backlog.

Urban transport

In growing urban areas, transport networks are coming under increasing pressure. Cars and buses in central Manchester or Bristol experience delays of more than 100 seconds per mile travelled.²¹ This compares to an average of 78 seconds on all urban A roads, 22 seconds on rural A roads and 9 seconds on

the intercity road network.²² Crowding on the railway is also focused on cities, particularly London, Manchester, Birmingham and Leeds.²³

Figure 4.1 shows that the capacity of road networks to deal with peak traffic falls with increases in the size of towns and cities, particularly in areas with populations above 100,000. The chart uses the Commission's newly developed measure of how quickly people can travel from where they live in a town or city (using the Office for National Statistics' 'built up areas' definitions) to that town or city's centre of employment. The dataset and technical details are available on the Commission's website. The chart uses the ratio of peak to off-peak connectivity for towns and cities to assess capacity constraints. A value of 1 implies that the connectivity is the same at peak and off-peak times. Lower values imply constraints at peak times. As settlement size increases, road networks become increasingly less effective at managing peak demands.²⁴

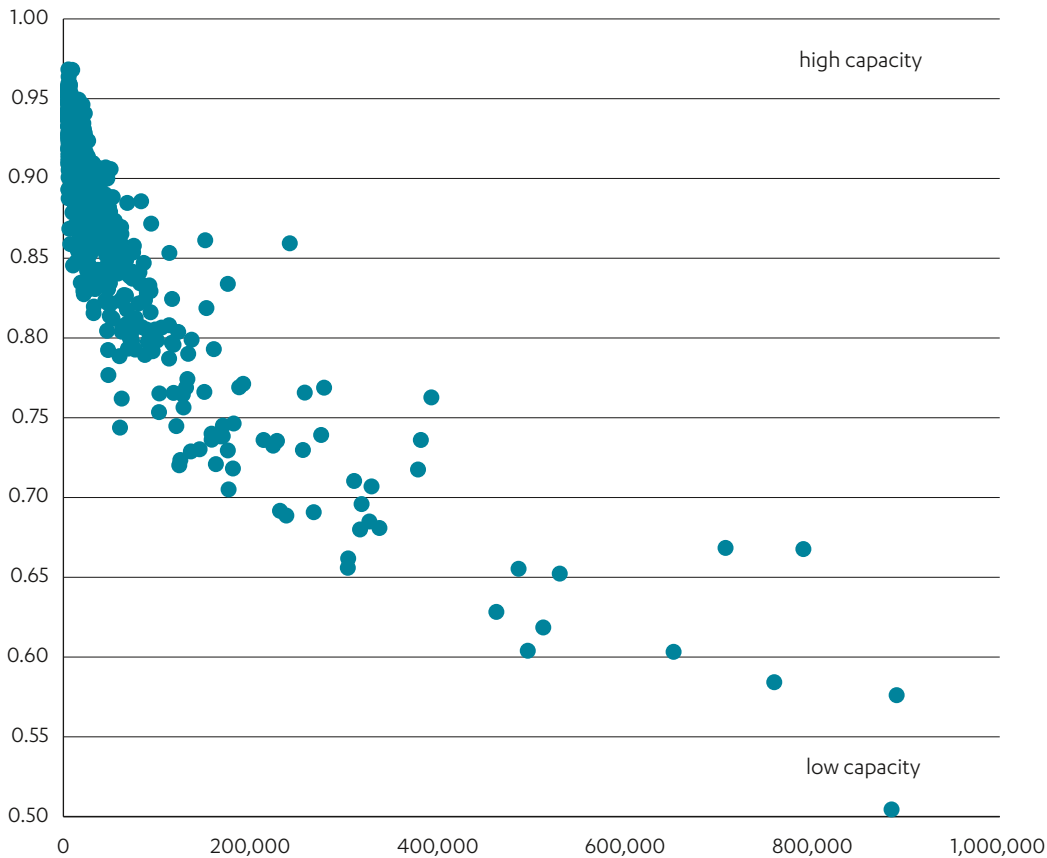


Figure 4.1: Built up area population and ratio of peak to off-peak connectivity for built up areas with population under 1 million²⁵

Making best use of limited space

More investment in public transport, alongside the promotion of safe cycling and walking, is the only way that cities can increase their infrastructure capacity to support growth. Connected and autonomous vehicles could have a positive impact on intercity transport, but they will never be an effective replacement

for high capacity public transport in dense city centres and may simply increase pressures on road space.²⁶

New forms of public transport – from dockless cycle or even electric scooter hire to autonomous buses – are emerging. City leaders need to consider how to manage the impacts of changing travel patterns in their transport planning. But the basic challenge of urban transport is still the same: there is simply not enough space in cities for everyone to travel by car.

Typically new roads lead to new journeys, filling up the additional space.²⁷ But, as shown in figure 4.2, it is possible to increase capacity by investing in high capacity public transport.

Transport mode	Typical maximum capacity per lane (inbound passengers per hour)
Car (1.2 people – current commuter average)	720
Bus	1,800
Bus rapid transit	2,100
Tram	2,880

Figure 4.2: Maximum system capacity for different modes of transport²⁸

A less car focused approach to urban transport can also bring other benefits, including:

- the opportunity to build well designed city centres focused on people's needs
- reallocating space from roads and parking to pedestrianised areas, leisure amenities and green space
- better, safer provision for cycling and walking
- improved transport networks that are more accessible for older and disabled people
- infrastructure aligned with schemes to bring brownfield land back into use, which can help regenerate inner cities.²⁹

Poor air quality is also a significant cost of cities dominated by petrol and diesel cars, and has a damaging impact on health. However, in the long term widespread adoption of electric vehicles will reduce the harm caused by this, so it is important that cities help to facilitate the rapid uptake of electric vehicles, as set out in Chapter 3.

Improving transport in every city

Government should make sure all cities are able to deliver the appropriate transport infrastructure in their area. This requires changes in strategy development, funding and governance for urban infrastructure in cities outside London.

Strategy development

Transport policy should not be about schemes. Investment needs to enable the journeys that allow people to live and work where they want to, and to connect people to wider services. Decision makers need to understand all the characteristics of the local economy, environment and geography. Transport policy needs to be integrated with a clear strategy for where housing growth can be accommodated in and around cities, and where employment growth is likely to occur. Linking transport enhancements to housing growth is essential to get the most value from investment.

City leaders should implement long term plans for their city-region reflecting their own economic and social priorities, based on their own local knowledge and accountability. These need to integrate transport, housing and employment. Other urban infrastructure, such as digital (see Chapter 1), electric vehicle charging (see Chapter 3) and flood resilience (see Chapter 5) also needs to be considered.

Recent government policy on devolution has meant cities increasingly have the right powers and governance to tackle these issues, particularly in cities with mayors. However, integration of strategies for transport and housing requires integration of decision making. Currently, leaders in large cities need unanimous approval from individual districts to all aspects of any integrated development plan, limiting the level of ambition. This needs to be addressed to maximise the value from new urban transport infrastructure.

Beyond this, a lack of long term funding means that, outside of London and Manchester, few cities have developed integrated strategies, since there has been no realistic prospect of being able to implement them. In some cities, this has also led to a lack of strategic capacity.

Funding

Local leaders making long term plans for their cities need long term certainty on funding. There is a lack of long term, stable and certain funding structures to support investment in urban transport outside London. City and local leaders have to bid to many different government competitions, which provide an unpredictable and short term funding stream and place a significant strain on the limited revenue funding available for transport planning.³⁰ The government's recently created Transforming Cities Fund improves on previous funding arrangements by giving mayors more flexibility over their funding allocations,

and simplifying requirements before funding decisions can be made. But more progress is needed.

Local transport authorities outside London should have stable, devolved infrastructure budgets, as Highways England and Network Rail have. The devolved budget should comprise of five year settlements, with fixed annual budgets set at least two years before the start of the five year period. This budget should be sufficient to cover all maintenance, small to medium enhancement projects and programmes to deploy or pilot new smart infrastructure technologies.

Devolved infrastructure budgets will be a replacement for Department for Transport and Local Growth Fund grants for local infrastructure, and they will be complementary to the funding that authorities can raise locally through fare income and other local revenue sources.

Maintenance allocations should be determined according to the cost of keeping the relevant infrastructure assets held by the authority in working order. Funding for small to medium enhancement projects in cities should be allocated according to the size of the city, the city's density, and evidence that the city's projected growth will outstrip its existing infrastructure capacity.

Increased funding for cities should be available to all cities with a population over about 100,000 to reflect the higher infrastructure needs of denser urban areas. This broadly matches the definition of 'primary urban areas' (54 cities in England outside London).³¹ Whilst there is no perfect boundary, a population of around 100,000, as shown in figure 4.1, is the point at which capacity constraints become most serious.

The level of funding for devolved infrastructure budgets in cities should ensure their spending power increases by around 10 per cent during the 2020s compared to current urban transport investment, an increase of approximately £300 million per year, and increases by around 30 per cent or over £1 billion per year by the mid 2030s. This totals around £12 billion from 2020 to 2040. Chapter 7 sets out the choices that the Commission has made within the resources set out by the government. With large existing commitments, such as HS2, in the 2020s, new funding for cities has to build up gradually. Funding for authorities outside cities should remain broadly at current levels.

To ensure the long term stability of funding for cities and local authorities, government should legislate for an obligation to publish infrastructure allocations in advance. In the future, government should also consider whether local tax raising may be more appropriate than central government grants.

As well as increased funding for investment, it is important that local infrastructure authorities have the resources they need to increase their transport capacity. Government should therefore ensure sufficient revenue funding is available for local project development, network management and bus operations, especially in cities.

Governance

The appropriate authority to make decisions on how to invest devolved urban infrastructure funding will usually be one that already exists: a mayoral combined authority, combined authority or unitary authority. But some cities have no urban infrastructure authority of their own and are served by a county council. In these cases government should ensure that arrangements are put in place for an appropriate urban infrastructure authority.

Once funding is devolved to local authorities, central government should not have powers over how it is spent. Cities will need to coordinate with Highways England and Network Rail and may, in some cases, choose to use some of their resources for enhancements to the strategic networks in partnership with them. Local authorities should be expected to make evidence based decisions, evaluate performance of their investments and publish information enabling them to be held to account by local people on how they have invested in infrastructure. Chapter 6 sets out the Commission's proposals on how to use better data to improve the appraisal and selection of projects. In cases of serious failure, government could withdraw funding devolution.

The Commission recommends that cities should have the powers and funding they need to pursue ambitious, integrated strategies for transport, employment and housing.

- **By 2021, metro mayors and city leaders should develop and implement long term integrated strategies for transport, employment and housing that will support growth in their cities.**
- **By 2021, government should ensure city leaders have the right powers to deliver these integrated strategies, including the power for metro mayors to make decisions on major housing development sites.**
- **Government should set out devolved infrastructure budgets for individual cities for locally determined urban transport priorities in line with the funding profile set out by the Commission. Budgets for 2021-2026 should be confirmed by mid 2019. Government should pass legislation, by 2020, requiring cities to be given regular five year infrastructure budgets.**

Infrastructure to support housing

Infrastructure needs to promote new housing and new communities in areas where they are needed. 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.

Siloed planning and delivery of utilities infrastructure and housing means that providing utilities to new housing developments can often be a cause of delay to construction. Consultation responses to *Congestion, Capacity, Carbon: priorities for national infrastructure* identified three causes.

Firstly, there is a tension between the requirements on regulators to protect consumers from price rises and to invest in future infrastructure provision, which can generate perverse outcomes for the delivery of timely infrastructure. In particular there is a lack of incentive for utility companies to develop increased capacity in advance of development, putting these costs on housebuilders. This can create coordination failures where upgrades are large and exceed the needs of any individual development.

Secondly, the diversity of organisations (the Distribution Network Operators, the industry regulators, local planning authorities) involved in the planning, design and delivery of utilities infrastructure in England leads to division and poor communication. And thirdly, there is a lack of mechanisms to improve coordination between housing and infrastructure for smaller scale housing developments.

The Commission will conduct more detailed analysis on the role of utilities in the delivery of housing, working with stakeholders and liaising with ongoing studies.

The next wave of infrastructure upgrades

Substantial funding must be set aside for major upgrade programmes in the city-regions that need them the most, in addition to the devolved funding for small to medium enhancements. London has had the advantage of receiving exceptional funding for upgrades to capacity such as Crossrail. Other cities should have this benefit too. This could provide cities in the UK with major capacity upgrades such as metros or bus rapid transit.

Major upgrade programmes require higher levels of funding to be concentrated in a few areas temporarily, and even fast growing cities do not require transformative upgrades on a continuous basis, meaning that a process of prioritisation is required. Funding should be agreed for major new capacity programmes in cities where infrastructure is the most significant constraint on growth. Identifying programmes will take time; most cities have not developed plans at this scale because they have lacked funding streams that could realistically deliver them. In some cities, it will be important to build capability in strategy, procurement and delivery before launching major investment programmes.

Before funding is agreed, cities should commit to additional housing development alongside new transport, linking employment growth to new homes. They should also be able to demonstrate that they can provide a local contribution to project costs, as for Crossrail 2, although the proportion may need to vary to reflect regional circumstances.³² This contribution should include local fundraising, potentially through fares or local taxes.

Central government should work closely with cities before making final commitments to funding. Not everywhere will need major investment. The initial phase should identify priority cities. Figure 4.3 illustrates how capacity constraints and expected employment growth vary considerably between cities. This uses the Commission's new measure of transport connectivity (see figure 4.1)³³ and employment growth estimates³⁴ derived from Office for National Statistics' population projections (which roll forward data from the recent past, adjusting for demographics, and are not forecasts).

Having identified priority cities for the first wave, government should work with them as they develop specific project proposals to support growth. When final proposals are submitted to government, they should also be reviewed by the Commission. The government should then make final decisions on major upgrade programmes and allocate funding, making long term commitments into future spending review periods where necessary.

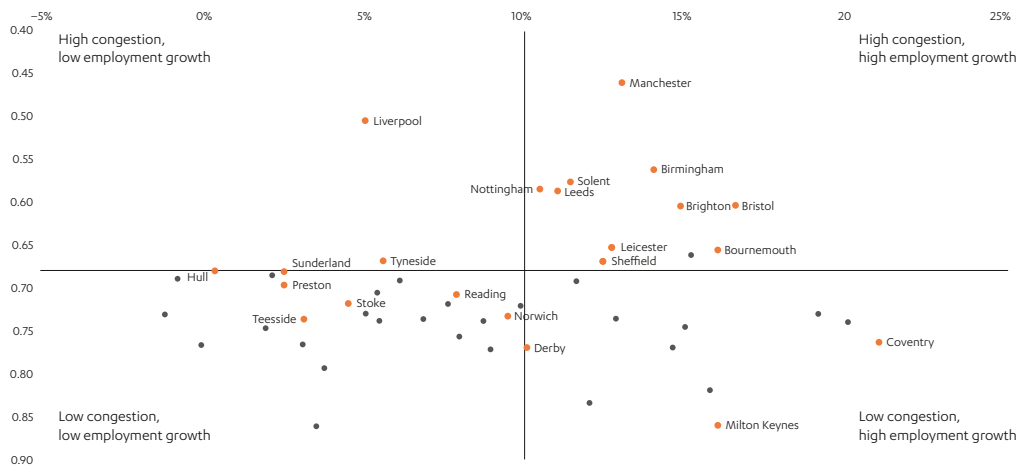


Figure 4.3: Capacity constraints on the roads and employment growth projections for 2018-50 within city centres outside London, based on Commission analysis.

Note: The 25 largest cities by employment are shown in orange, with smaller cities in grey. Cities further to the right are projected to grow faster in their city centre, while cities nearer to the top have greater capacity constraints into the city centre.³⁵

Not all cities will need large scale investments. In some, existing capacity and incremental enhancements will be sufficient. Others that are not included in the first wave should be considered for inclusion in future rounds of funding, especially where lower cost interventions, such as bus schemes, have identified demand in key transport corridors. Given the long term funding being proposed

(major capacity programmes could easily need to be funded for 5-10 years) future rounds should take place no more than once or twice per parliament. It is essential that the process makes choices about the most important investments rather than giving many small funding grants. Around £31 billion is required by 2040 for major urban transport capacity programmes, delivering on growth needs over that period and preparing for future growth.

The Commission recommends that government should allocate significant long term funding for major capacity upgrades in selected growth priority cities, in line with the funding profile set out by the Commission. Cities benefiting from major projects should make commitments on housing delivery and provide at least 25 per cent of funding. Priority cities should be identified by mid 2019, with long term investment commitments agreed by 2020. Future rounds should take place no more than twice a parliament.

London

Development of regional cities should be in addition to and not instead of continuing to invest in London. The UK's highest value jobs continue to be in London and it is projected to grow faster than anywhere else, with employment growing 18 per cent to 6.7 million by 2041.³⁶ Taxes paid in London and its surrounding regions fund infrastructure and other services in other regions of the UK, contributing £3,070 per person to the rest of the UK in 2016.^{37,38} And it is an internationally competitive city; infrastructure constraints on London's growth are as likely to cause displacement overseas as they are to elsewhere in the UK.

London's transport networks are already more congested and overcrowded than anywhere else in the country. Future growth will not be possible without substantial increases in capacity. The Commission has already recommended that Crossrail 2 should go ahead to increase capacity into central London. The Mayor's Transport Strategy sets out a wider range of interventions that will be needed, including improvements to bus networks, cycling infrastructure, the Underground and suburban rail lines.³⁹

Most of the proposals contained in the Mayor's Transport Strategy would be delivered by Transport for London. Transport for London plans to cover all its operational expenditure through its own operational income in future, but it will still need support for investment, which should be sustained at current levels. The government should continue to work with the Mayor to fund Crossrail 2 as recommended by the Commission.

Endnotes

- ¹ Eurostat (2018), Gross value added at basic prices by NUTS 3 regions; Eurostat (2018) Employment (thousand persons) by NUTS 3 regions; ONS (2018) Annual population survey – workplace analysis (accessed through Nomis)
- ² There is no single UK definition of a city. Except where stated otherwise, this chapter uses the “primary urban area” definition originally developed for the State of the English Cities reports (Office of the Deputy Prime Minister, 2006 and Department for Communities and Local Government, 2011) and updated by the Centre for Cities in 2016, corresponding to cities with a population of around 110,000 or over. Under this definition there are 55 cities in England.
- ³ National Infrastructure Commission (2017), Economic growth and demand for infrastructure services
- ⁴ Centre for Cities (2018), Cities Outlook 2018
- ⁵ Martin et al. (2016) Future of Cities: Working Paper. Divergent cities in post-industrial Britain, report prepared for Foresight, Government Office for Science
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- ⁸ National Infrastructure Commission (2016), The impact of population change and demography on future infrastructure demand
- ⁹ See figure 4.3
- ¹⁰ Centre for Cities (2016), Competing with the continent, how UK cities compare with their European counterparts
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- ¹⁴ Department for Transport (2016), National Travel Survey Table NTS9911, average number of trips by trip length, region and rural-urban classification, England, 2014/15
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- ²² Department for Transport (2018), Travel time measures for the Strategic Road Network and local ‘A’ roads: January to December 2017
- ²³ Department for Transport (2017), Rail passenger numbers and crowding on weekdays in major cities in England and Wales: 2015 (revised)
- ²⁴ The chart shows settlements with population size up to 1 million. Larger settlements show the same pattern, but are hard to show on the same chart without distortion, since their population is so much greater. Values for the ratio of peak to off-peak connectivity are: Greater London 0.24, Greater Manchester 0.46, West Midlands, 0.56, West Yorkshire 0.59.
- ²⁵ Prospective (2018) Transport connectivity final report, report for the National Infrastructure Commission
- ²⁶ Wadud et al (2016), Help or Hindrance? The travel, energy and carbon impacts of highly automated vehicles, Transportation Research
- ²⁷ Duranton and Turner (2011) The fundamental law of road congestion
- ²⁸ Steer Davies Gleave (2018), Urban transport network review, report for the National Infrastructure Commission
- ²⁹ Urban Transport Group (2018), Active Travel: solutions for changing cities; Mayor of London (2017), Healthy Streets for London; Centre for Cities (2014), Delivering change: building homes where we need them
- ³⁰ Urban Transport Group (2016), Policy Futures for Urban Transport
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- ³³ Prospective (2018) Transport connectivity final report, report for the National Infrastructure Commission
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5. REDUCING THE RISKS OF DROUGHT AND FLOODING

BEING RESILIENT TO EXTREME WEATHER

Climate change increases the risk of both flooding and drought in England

This is already having an impact, and will do in the future:

High flood risk:

1 million

homes have more than 1% chance of flooding in any given year



But also a strong risk of drought:

1 in 4

chance of a severe drought between now and 2050



RESILIENCE SAVES PEOPLE FROM THE TRAUMA OF FLOODING AND THE COSTS OF DAMAGE AND INSURANCE

The Commission have proposed a national standard so that by 2050 communities will be resilient to flooding

99.5%

of the time wherever feasible



This means that someone living in a house at risk of flooding for 20 years would face only a 1 in 10 chance of flooding over that time

BUT WE ALSO NEED TO BE MORE RESILIENT TO DROUGHT

Relying on emergency measures would cost an estimated

£40 billion

Over the next 30 years – being resilient would cost only £21 billion


The UK needs an extra

4,000MI


of water a day to assure long-term supply



THE COMMISSION RECOMMENDS:



A national standard of flood resilience with a higher standard in major urban areas



A national water transfer network and new water supply, such as reservoirs



Nationwide, catchment-based plans combining green and grey infrastructure



Halving leakage by 2050 and reducing demand through efficiency and smart metering

Sources: Commission calculation using inputs from Atkins, Environment Agency, ITRC and Regulatory Economics

Climate change will increase the risk of both flooding and drought. Despite several significant incidents over recent years, the risks continue to rise, and planning has been disjointed. Action is needed now to make communities resilient for the future, rather than waiting until the situation gets worse.

About 5 million properties in England are currently identified to be at risk of flooding. Of these, about 600,000 homes have more than a 1 per cent chance each year of being flooded by rivers and the sea.¹ A similar number have more than a 1 per cent chance each year of flooding from surface water.² Floods affect people's lives and health as well as causing economic damage.

While it will never be possible to prevent all flooding, the current approach is too piecemeal and too reactive. Government should ensure that all communities are resilient, so they are able to cope with, and recover from, flooding. There should be a long term national programme: resilience cannot be increased everywhere overnight and the extra funding needed will only become available gradually. But a long term strategy, with long term funding, can deliver a national standard by 2050.

At the same time, households and businesses in large and densely populated parts of England face significant risk of having their water supplies rationed because of drought. While water companies' plans show some progress in addressing this risk, they fall short of what is needed. The Commission's 2018 report *Preparing for a drier future: England's water infrastructure needs*³ set out the action needed for drought resilience.

To minimise the impact of severe weather and climate change, England requires:

- a long term strategy to ensure that all communities are resilient to severe flood events by 2050, with higher standards for the most densely populated areas
- increased resilience to drought through a national water network, halving the water lost through leaks, and reducing demand through smart metering

A lack of reliable data has meant that it has not been possible to consider surface or waste water in detail for this Assessment. Surface water flooding is significant⁴ and there has been little progress in the decade since the Pitt review.⁵ Further work is needed urgently.

The risk of flooding

Climate change is expected to both increase rainfall in winter and decrease it in summer, as shown in figure 5.1. Together with population growth, this will lead to greater risks of both flooding and drought.

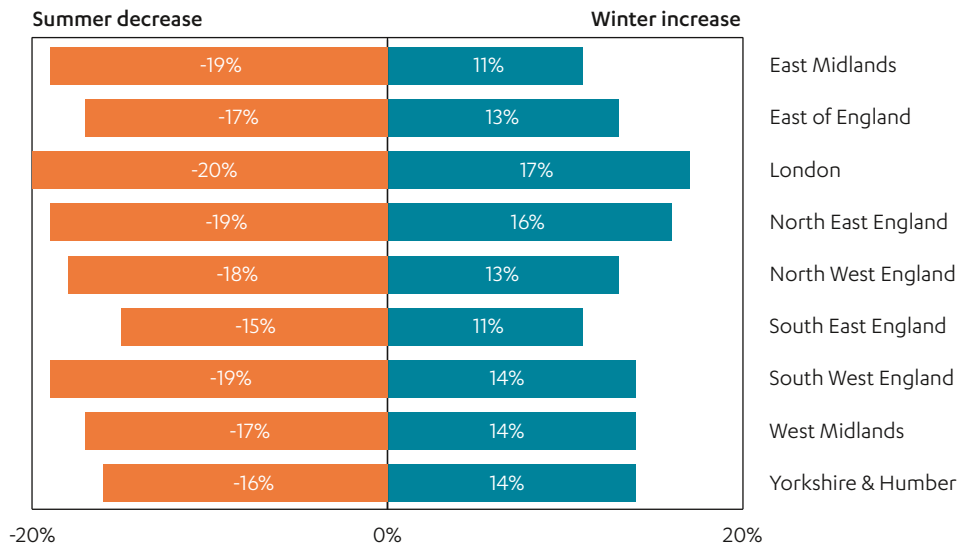


Figure 5.1 Projected changes in summer and winter precipitation by 2050⁶

Note: changes for 50% probability in the 2050s assuming medium emission scenario.

The likelihood of drought and flooding is expressed as an annual probability. For example, a 1 per cent annual probability of flooding corresponds to a 1 in 100 chance of a particular area being affected each year. As there are many areas at risk of flooding across England, there is a high chance that at least one will be flooded by a 1 per cent event in any year. Probabilities can only be an estimate: in particular, the uncertain impacts of climate change limit the ability to forecast future risk precisely. Care should be taken in interpreting specific figures, but scenarios allow a broad assessment of plausible future flood risk. Further details and references to the assumptions and analysis are in the technical annexes: *Flood modelling and Analysis of drought resilience*.

Increasing numbers of households across England are at risk of flooding in severe events (shown in figure 5.2), but long term objectives for flood risk management are unclear. Levels of risk and investments vary widely across otherwise similar places and there is no certainty of whether or when preventative action will be taken.

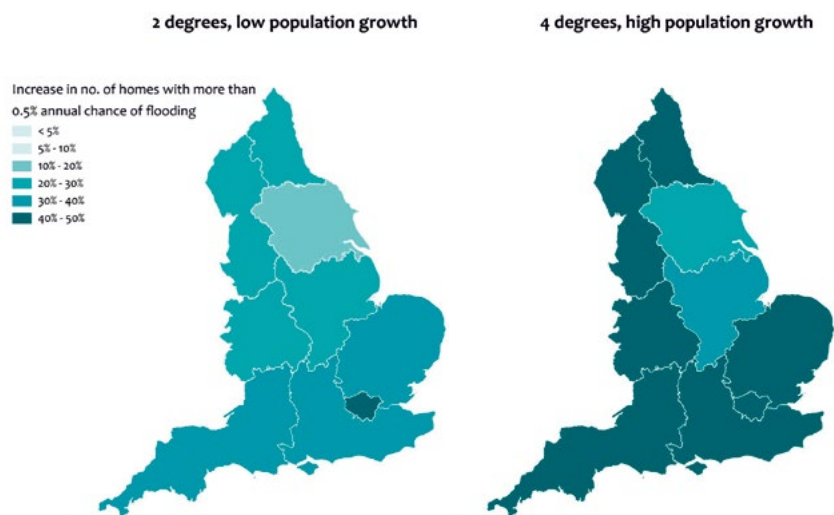


Figure 5.2 Percentage increase in homes at 0.5 per cent or greater annual chance of flooding in future population and climate change scenarios⁷

Flooding has significant impacts on the local community including disruption, loss of employment, and mental ill health as well as direct impacts on buildings and property.⁸ Insurance can help, and is currently subsidised for homes at most risk, but only covers some of the impacts.

A national standard of flood resilience

Management of flood risk over recent years has too often been short term and reactive. In the past, government budgets for flood risk management have been reduced, only to be increased again after floods: budgets were reduced in 2006/7 and 2007/8 but then increased following floods in 2007, and cut again in 2011/12 with a large increase following floods in the winter of 2013/14.⁹ It would clearly be better to build flood resilience before it is needed. The six year capital programme agreed for 2015/16 – 2020/21 provides greater certainty and should result in more efficient planning. However, there is no clear long term objective for the level of flood resilience that the government is seeking to achieve.

Decisions about capital investment in flood risk management have generally been made on the basis of cost benefit analysis. Essentially, this involves an assessment of whether it is ‘worth’ protecting particular homes and commercial properties. This is not a sustainable basis for decision making. Properties at risk of flooding are seldom abandoned or adapted to cope with the risk, so people are left to live with the risk. Subsidised insurance can incentivise homeowners in flood risk areas not to take any action. Without a clear objective, it is harder for the Environment Agency to take a strategic view across a whole catchment, although some catchment based plans have been made.

A better approach would be to set a nationwide objective for a minimum level of resilience wherever feasible. This has public support: the Commission’s social research showed that 59 per cent of people thought everyone should receive the

same level of protection, even though in some areas it would cost more, with only 16 per cent against.¹⁰ However, a national standard should not be statutory or imply a right to compensation if not achieved.

Setting a standard

There is no absolute way of setting the right standard. What is affordable and achievable will vary over time. The Commission has considered what standards would be reasonable by 2050. Over longer time periods, higher standards might be achievable.

The Commission has analysed the investment that would be required to provide a range of resilience standards across different settlement types for river and sea flooding. Average annual capital costs between 2020 and 2050 are shown in figure 5.3, based on a climate change scenario equivalent to a 2°C increase in global mean temperatures.

The costs were estimated using recent Environment Agency data on flood risk management activities. The modelled cost per property varies depending on the property's current and future risk, whether it benefits from existing flood defences, property density and source of flooding.¹¹ The baseline assumes that current resilience is maintained, broadly following the Environment Agency's Long Term Investment Scenarios.¹² Further details are in the technical annex: *Flood modelling*.

The modelling produces estimates of the costs of a national standard of resilience to flooding with 1 per cent, 0.5 per cent or 0.1 per cent annual probability, and additional costs for providing higher standards in the most densely populated areas.

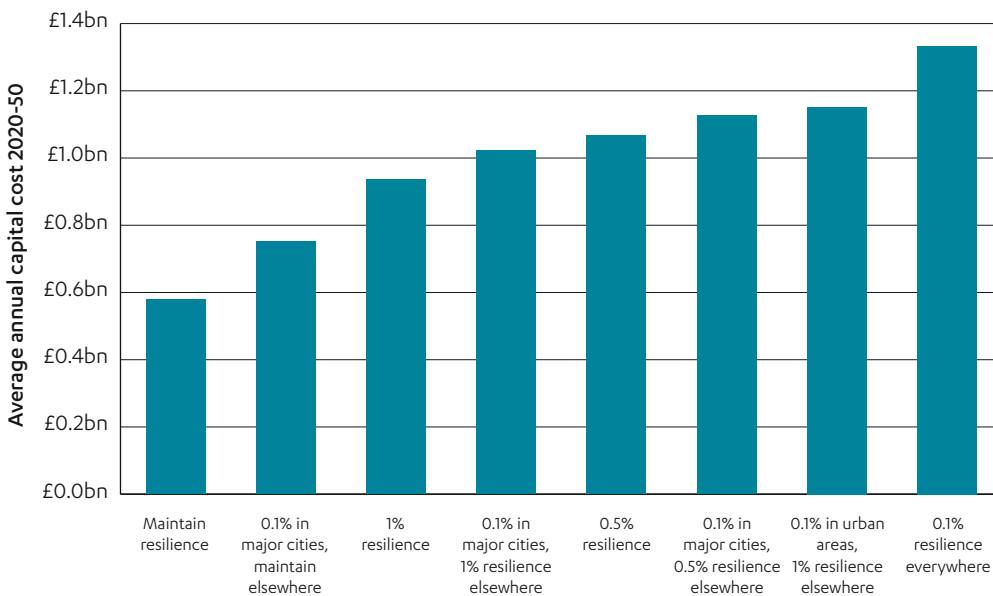


Figure 5.3 Estimated average annual public capital costs for different standards of resilience to flooding from rivers and the sea, 2°C increase in global mean temperatures climate scenario, 2017 prices, in England

The annual ongoing cost of a particular standard can be compared to the estimated avoided damage, including property damages, emergency response costs, risk to life and physical injury, mental health effects and impacts on infrastructure, transport, schools and leisure. Setting a national standard will ensure that society as a whole is better off, but without requiring that each home or commercial property justifies its level of flood resilience.

Whilst the estimated costs of nationwide flood resilience are up to three times current investment, the benefits (reduced damages) exceed costs for the range of standards. Estimates are inevitably uncertain; climate change means weather patterns, and therefore the scale of impacts, may fall outside the range of available data.

The Commission's judgement is that all properties, wherever feasible, should be resilient to severe flooding, with a 0.5 per cent annual probability, by 2050. This is consistent with the advice provided to government by the Natural Capital Committee for the 25 year Environment Plan.¹³ Under this standard, someone living in a house at risk of flooding for 20 years would face less than a 1 in 10 residual chance of being flooded.

Densely populated areas

A higher standard should be provided for the largest cities, with populations over half a million. This reflects the lower cost per property for protecting densely populated areas¹⁴ and the potential for natural disasters in cities to result in cascading failures, putting severe pressures on disaster response. The largest cities provide a range of economic and social services to their region as a whole, not just to those who live within them, so the potential impact of flooding is greater.

Precise estimates of probability for extreme events are hard to obtain. Economically important locations should be stress tested against a range of plausible extreme events. The Thames Barrier was designed for sea levels with an annual probability of 0.1 per cent. The Commission's analysis has assumed the same standard for the largest cities.

Climate change scenarios

The Commission undertook similar analysis for a climate change scenario equivalent to a 4°C increase in global mean temperatures. The costs of achieving each resilience standard in a 4°C world are much higher than for the same standard in a 2°C world, but so are the benefits.

This might suggest a precautionary approach of building resilience against higher climate change. However, flood resilience can be designed to be enhanced incrementally. Measures that provide resilience in a 2°C world can be upgraded if it becomes apparent that a 4°C world is more likely. This 'adaptive management' is consistent with catchment based approaches using a range of interventions, rather than just conventional flood defences. This is the most appropriate

approach until there is more certainty on climate change impacts, allowing resilience standards to be increased over time.

The Commission recommends that government should set out a strategy to deliver a nationwide standard of resilience to flooding with an annual likelihood of 0.5 per cent by 2050 where this is feasible. A higher standard of 0.1 per cent should be provided for densely populated areas where the costs per household are lower.

A long term strategy for flood resilience

A clear objective will allow for a long term, national strategy for flood resilience. The Environment Agency are due to update their National Flood and Coastal Erosion Risk Management Strategy in 2019. This should expand on the 25 Year Environment Plan to set out how these standards of flood resilience can be achieved by 2050.

Delivering the strategy will require action on long term funding, updated catchment and shoreline management plans, surface water management and development control. Environment Agency monitoring of the strategy should include data on the number, locations and resilience of properties flooded from different sources and events each year.¹⁵

The strategy should set out a clear plan to deliver the proposed resilience by 2050, as well as ensuring that different aspects of flood management are joined up. It should make clear what is expected of different stakeholders and maximise the opportunities for partnership working. This should be backed up by a long term funding commitment, building on the existing six year capital programme, enabling efficient planning and delivery of projects to address the risk from all sources of flooding.

Catchment and shoreline plans

Existing Catchment Flood Management Plans and Shoreline Management Plans should be updated to take account of the new standard and set out long term plans for flood risk management across catchments and coastal cells. These plans should use the latest evidence to evaluate the full range of options to achieve the proposed resilience standard including traditional flood defences, 'green infrastructure' (whether natural flood management or sustainable drainage systems), individual property measures, spatial planning and coastal realignment or 'managed retreat.' They will need to take account of the replacement of the Common Agricultural Policy following the UK's exit from the EU which should support natural flood management. As risk can never be eliminated, flood warning, response and recovery will also continue to be important.

The plans will need to show how risk can be managed for all plausible climate futures. They should ensure interventions are adaptable to different futures and that climate change is factored into the design and construction of all

infrastructure. This should be undertaken in such a way that the plans can be updated to reflect new information on climate change with the minimum of effort.

Surface water management

The data needed to robustly assess the costs and benefits of different resilience standards for surface water flooding is currently unavailable. All relevant organisations should ensure data is available in good time for the next Assessment. Water companies are developing Drainage and Wastewater Management Plans. Water companies and local authorities should work together to build on their existing plans and take action on local flood risk where this is possible. This should include identifying communities at greatest risk from severe surface water flooding and developing joint plans, including investment requirements, to ensure resilience. These plans should inform the next Price Review and Assessment.

Development control

Preventing inappropriate housing development is essential for effective long term flood risk management. In 2016/17, 11 per cent of new homes were built in the floodplain¹⁶ and while many will have been designed to minimise the risk, long term sustainability and compliance is difficult to demonstrate. Consideration should also be given to development outside the floodplain which could increase risk, for example through increased surface water runoff.

The Commission recommends that, to deliver the strategy:

- **By the end of 2019, government should put in place a rolling 6 year funding programme in line with the funding profile set out by the Commission. This should enable efficient planning and delivery of projects and address the risks from all sources of flooding.**
- **The Environment Agency should update plans for all catchments and coastal cells in England before the end of 2023. These should identify how risk can be managed most effectively using a combination of measures including green and grey infrastructure, spatial planning and property level measures.**
- **Water companies and local authorities should work together to publish joint plans to manage surface water flood risk by 2022.**
- **The Ministry of Housing, Communities and Local Government and planning authorities should ensure that from 2019 all new development is resilient to flooding with an annual likelihood of 0.5 per cent for its lifetime and does not increase risk elsewhere.**

Drought resilience

A reliable water supply is usually taken for granted in the UK. But the country faces a real and growing risk of water shortages, especially in the south east of England. Climate change, an increasing population, and the need to protect the environment are bringing further challenges for an already strained system. And the pressure will only rise over the coming decades as shown in figure 5.4.

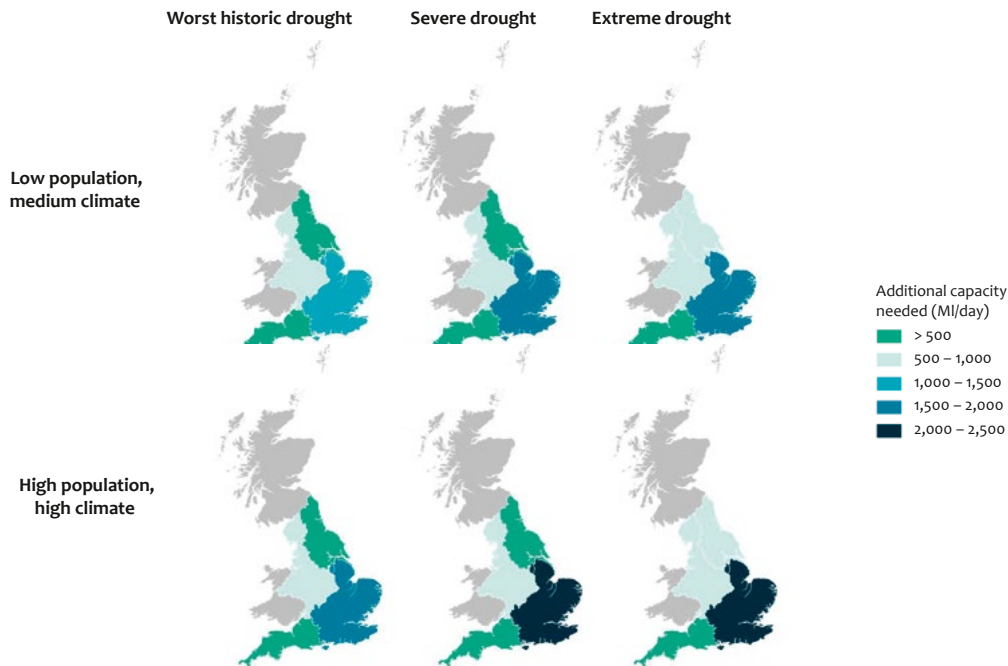


Figure 5.4 Additional water capacity for droughts with different population and climate scenarios¹⁷

Note: medium climate refers to an average medium emission scenario, high climate refers to a drier, medium emissions scenario with less water in the south east.

The full analysis is shown in the Commission's report *Preparing for a drier future* and the technical annex: *Analysis of drought resilience*. Conflicting incentives, limited cooperation between water companies and a short term focus have constrained action. As a result a serious drought would lead to an unacceptably high risk of severe supply limitations; homes and businesses could even be completely cut off.

Maintaining current levels of resilience until 2050 in the face of rising population, environmental and climate pressures, would require additional capacity of about 2,700-3,000 million litres per day (Ml/day) in England.¹⁸ Additional capacity required to protect the UK from extreme drought (0.2 per cent annual chance) is between 3,500 and 4,000Ml/day as shown in figure 5.5.¹⁹ The Commission's analysis shows that the costs of providing proactive long term resilience are less than those for relying on emergency response.

The Commission therefore believes that additional supply and demand reduction totalling 4,000Ml/day should be delivered by 2050.

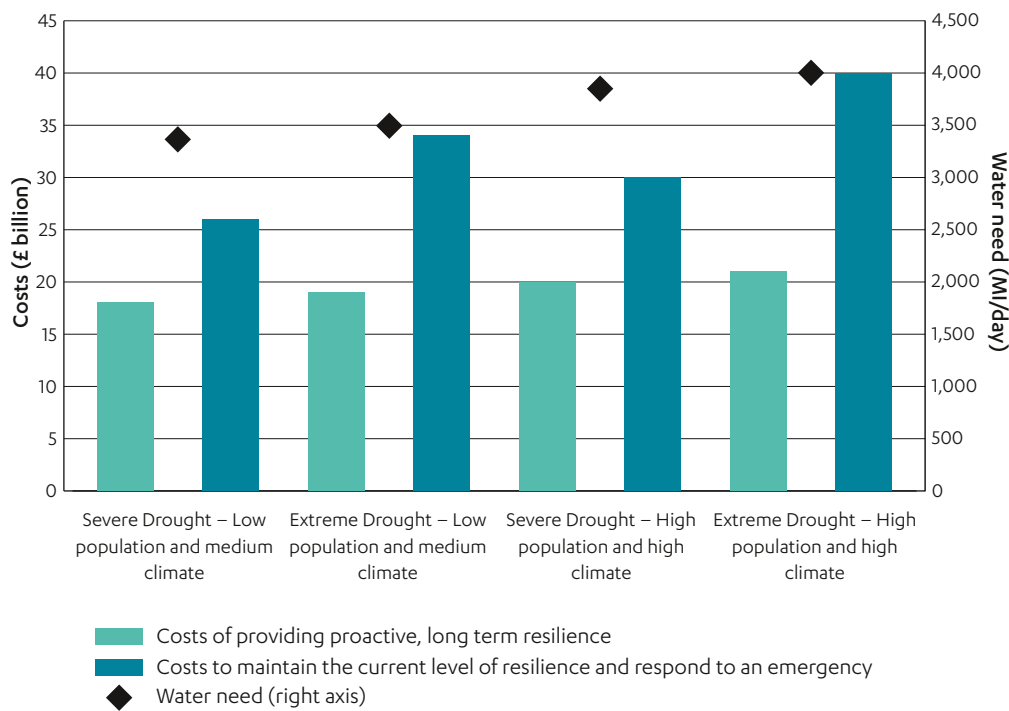


Figure 5.5 Costs of providing proactive, long term resilience and relying on emergency response for droughts beyond current resilience levels²⁰

Note: Costs are expected present values to 2050 (in 2018 prices) and include maintaining 1 per cent resilience, which is considered to be ‘business as usual’.

A ‘twin-track’ approach of reducing demand and increasing supply is the lowest cost and most sustainable way to increase resilience. And more ambitious long term plans are needed, as shown in figure 5.6. These should address leakage, enable water companies to undertake more comprehensive water metering and demand management, and ensure the delivery of a national water network, and other options for additional supply infrastructure.

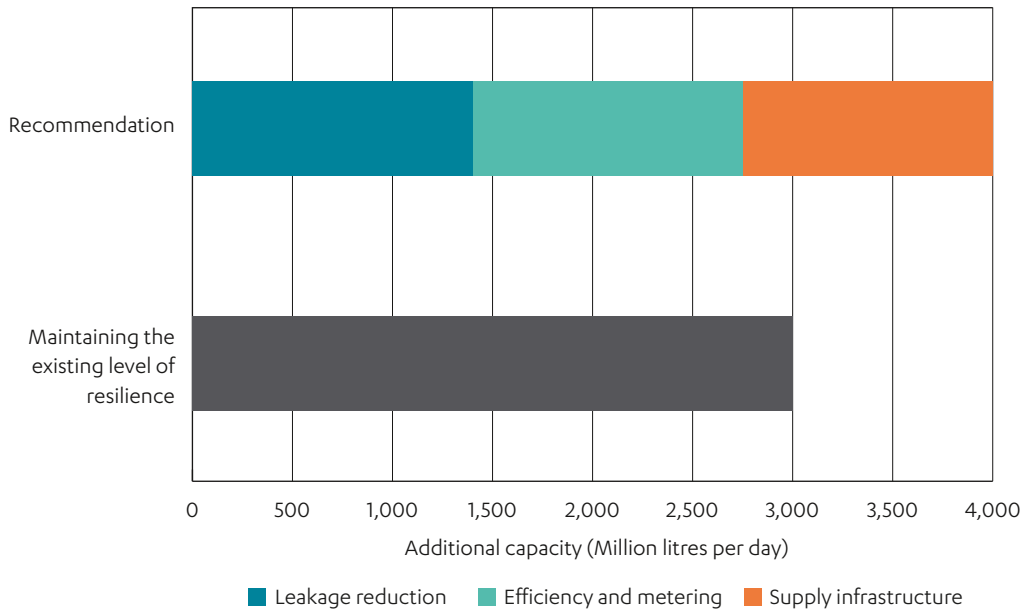


Figure 5.6 Twin-track approach addressing demand and supply²¹

Supply

Even with ambitious action to reduce demand, more supply infrastructure will be needed. Aiming for additional capacity of 4,000ML/day will require a minimum of 1,300ML/day additional supply infrastructure.²² Different options are available, including transfers, reservoirs, reuse and desalination. A range of studies have all found a positive cost benefit case for greater transfers and water trading.²³ A network of strategic water transfers, which can move water from areas with a surplus to those where it is needed, could provide about 700ML/day more capacity at comparable cost to other options and with increased adaptability of the overall system.²⁴ The remaining capacity should be provided by the most cost effective combination of supply infrastructure.

The scale of this infrastructure goes well beyond that seen in the draft plans proposed by water companies. It is likely to need strengthened regional approaches and an independent national framework. Ofwat has developed a 'direct procurement' mechanism for large infrastructure projects which could form the basis of open and transparent competition ensuring all options for significant additional supply capacity can be considered.

Demand

Demand reduction, including addressing leakage, can deliver the remaining 2,700ML/day needed. Today, around 2,900ML/day (20 per cent) of water put into the public supply is lost through leakage.²⁵ An ambitious long term strategy to reduce leakage would encourage action by customers and incentivise technological innovation, which should drive down the costs of managing leaks. Halving leakage should save over 1,400ML/day by 2050.

Conventional metering can reduce demand by around 15 per cent and smart meters are expected to reduce this further (to about 17 per cent) and help identify leaks.²⁶ Water companies can introduce compulsory water metering in water stressed areas. About 50 per cent of homes in England are currently metered and this is expected to reach around 80 per cent by 2050, saving around 400ML/day. Bringing forward metering more quickly would result in a further 400ML/day reduction in demand by 2050. In addition, efficiency improvements (as washing machines and toilets use less water, for example) are expected to reduce demand by around 600ML/day. There might be potential to go further in increasing efficiency, for example through local reuse schemes or labelling appliances, and companies should be more ambitious and show what can be achieved.

The Commission recommends that government should ensure that plans are in place to deliver additional supply and demand reduction of at least 4,000ML/day. Action to deliver this twin-track approach should start immediately:

- **Ofwat should launch a competitive process by the end of 2019, complementing the Price Review, so that at least 1,300ML/day is provided through (i) a national water network and (ii) additional supply infrastructure by the 2030s.**
- **The Department for Environment, Food and Rural Affairs should set an objective for the water industry to halve leakage by 2050, with Ofwat agreeing 5 year commitments for each company (as part of the regulatory cycle) and reporting on progress.**
- **The Department for Environment, Food and Rural Affairs should enable companies to implement compulsory metering by the 2030s beyond water stressed areas, by amending regulations before the end of 2019 and requiring all companies to consider systematic roll out of smart meters as a first step in a concerted campaign to improve water efficiency.**

Joining up flood and water management

A healthy aquatic environment is important for water supply and flood management as well as for biodiversity. Interventions to improve flood and drought resilience should consider the range of interactions that water has with people and the environment. There are opportunities for green infrastructure approaches that deliver multiple benefits including groundwater recharge, water quality and flood risk management.

The Environment Agency, local authorities and water companies should all work together to better coordinate their plans. The Environment Agency has a key role through its strategic overview for all flood and coastal erosion risk management as well as regulatory responsibility for water quality and abstraction. Appraisal and funding should encourage interventions that improve both drought and flood

resilience. Decisions on flood and water infrastructure should take into account the full range of potential benefits as well as wider impacts to ensure that all objectives can be delivered effectively.

Endnotes

- ¹ National Audit Office (2014), Strategic flood risk management and Environment Agency (2018), Risk of flooding from rivers and sea – key summary information
- ² Environment Agency (2014), Flood and coastal erosion risk management: Long-term investment scenarios
- ³ National Infrastructure Commission (2018), Preparing for a drier future: England’s water infrastructure needs
- ⁴ Pitt (2008), Learning lessons from the 2007 floods.
- ⁵ Committee on Climate Change (2017), Progress in preparing for climate change
- ⁶ Met Office (2014), UK Climate Projections: Medium emission scenario
- ⁷ Commission calculations using input from Sayers and Partners and JBA Consulting, for more details see technical annex: *Flood modelling*
- ⁸ Public Health England (2017), The English National Study for Flooding and Health: First year report
- ⁹ DEFRA (2017), Funding for flood and coastal erosion risk management in England
- ¹⁰ Ipsos MORI (2018), National Infrastructure Commission Phase 2: public research
- ¹¹ Sayers and Partners and JBA Consulting for the National Infrastructure Commission (2018), Floods standard of protections and risk management activities
- ¹² This is the same baseline assumed for the Committee on Climate Change (2017), UK Climate Change Risk Assessment 2017 Evidence Report
- ¹³ Natural Capital Committee (2017), Advice to Government on the 25 Year Environment Plan
- ¹⁴ Sayers and Partners and JBA Consulting for the National Infrastructure Commission (2018), Floods standard of protections and risk management activities
- ¹⁵ Section 18 of the Flood and Water Management Act (2010), requires the Environment Agency to report to the Minister about flood and coastal erosion risk management, including the application of the national strategy
- ¹⁶ Ministry of Housing, Communities & Local Government (2018), Land Use Change Statistics in England: 2016-17
- ¹⁷ Commission calculations, based on data from Water UK, water companies and the Environment Agency and using the NISMOD model developed by the Infrastructure Transitions Research Consortium
- ¹⁸ To put this in context, the typical volume of water available to supply households and businesses averages 15,000 Ml each day
- ¹⁹ This represents the need beyond intra-company transfers and small interventions needed to maintain existing capacity
- ²⁰ Commission calculations and analysis, using input from Atkins, Infrastructure Transitions Research Consortium and Regulatory Economics. See technical annex: *Analysis of drought resilience* for more details and references
- ²¹ Commission analysis, using input from Infrastructure Transitions Research Consortium and Regulatory Economics, see technical annex for more details and references
- ²² This represents the need beyond intra-company transfers and small interventions needed to maintain existing capacity
- ²³ Deloitte (2015), Water trading – scope, benefits and options; Cave (2009), Independent Review of Competition and Innovation in Water Markets; Ofwat (2010), A study on the potential benefits of upstream markets in the water sector in England and Wales; Ernst and Young (2011), Changing course through water trading
- ²⁴ However, there are also risks; for example, transfers can enable invasive species and pathogens to spread, so options need to be considered on a case by case basis
- ²⁵ National Infrastructure Commission (2017), Congestion, Capacity, Carbon: Priorities for National Infrastructure
- ²⁶ Based on expert consultation, and averaging values in literature including Sonderlund et al. (2014), Using Smart Meters for Household Water Consumption Feedback, *Procedia Engineering* 89, 990 – 997; Ornaghi and Tonin, The Effects of the Universal Metering Programme on Water Consumption, Welfare and Equity; evidence provided by Thames Water, Anglian Water and Severn Trent water. See also the technical annex *Analysis of drought resilience*

6. CHOOSING AND DESIGNING INFRASTRUCTURE



The UK needs to have confidence in its decision making and its ability to deliver innovative, world-leading, well designed infrastructure projects. It must make effective and timely decisions, and prioritise getting the best value out of its infrastructure projects over their lifetime.

The Commission was established to address many serious weaknesses in infrastructure decision-making. Policy uncertainty, reversals and prevarication have driven up costs and hampered delivery, with short term considerations often leading to decisions on controversial projects being postponed or, alternatively, taken in a rush without considering the evidence.

Better decisions can be taken. Part of this is to improve the processes by which individual projects are assessed and designed. This requires:

- improving project appraisal by collecting better data on outturn costs and benefits of major infrastructure projects
- ensuring quality design in future nationally significant infrastructure projects
- developing a clear framework for measuring infrastructure performance.

Delivery of high quality infrastructure 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 procure and act as an intelligent client for infrastructure. The UK's exit from the EU will impact the UK's skills base and supply chain; there should be a strategic approach to manage this. These areas are the remit of the Infrastructure and Projects Authority, rather than the Commission. Therefore, they are not covered in this chapter, but they remain critical.

Choosing projects

Government needs a robust approach to assessing the costs and benefits of infrastructure projects. Cost benefit analysis (also known as economic appraisal) is widely used to assist in deciding between infrastructure projects in the public sector, especially for transport projects. The UK is generally thought to be a leader in cost benefit analysis.¹ The Commission has engaged with a range of experts and interested stakeholders over the past year to better understand the limitations of existing methods and assess where improvements could be made.² Issues include:

- capturing system wide effects, rather than simply the marginal impact of individual projects

- the treatment of uncertainty – too often a single number is presented which does not reflect the range of possible outcomes
- ensuring the process does not become overly precise and focused on a preferred option at too early a stage.

Improving data

These are not straightforward issues to address. The Commission intends to continue working with experts and interested parties to find solutions. One key area where immediate progress could be made is in addressing the lack of consistent and publicly available outturn data on the costs and performance of infrastructure projects. In many cases, considerable time and energy is devoted to estimating expected costs and benefits but very little on establishing actual costs and benefits when projects are built.

Better data would allow:

- decision makers to understand the range of uncertainty in project appraisals by showing how outcomes have varied for similar projects, mitigating the natural tendency to optimism in assessing costs and benefits³
- consideration of a wider range of approaches at an early stage, by highlighting historic examples of successful alternatives to decision makers
- simplification of the early stages of appraisal, basing initial estimates on results from comparable projects
- greater scrutiny of proposals, at a stage when decisions are still open
- a more balanced understanding of past success and failure, in place of an excessive focus on the best or worst cases
- a better understanding of how different procurement and financing models affect outcomes (see Chapter 7).

The Commission's technology study, *Data for the public good*, identified the potential economic benefits from collecting and sharing infrastructure data. It recommended that the Infrastructure Client Group should cultivate a shift towards minimum levels of commercial confidentiality in the infrastructure industry.

Highways England routinely publish outturn project evaluations of major investments. This system has led to more accurate estimates of the likely costs of future projects, reducing the average error in forecast costs by 20 per cent between 2000 and 2009.⁴ Other public bodies could adopt a similar approach.

Historic outturn costs and performance data from major projects, which are appraised individually to a high level of detail, will be of greatest value. The

inclusion of historic data is vital to ensure that these datasets can inform decision making. Data should be reported on at least projects with a whole life cost above:

- £10 million for flood management
- £100 million for roads
- £500 million for rail

Cost data should be routinely comparable between initial estimates and actual outturns. Similarly, direct measures of benefit, such as whether passenger numbers meet expectations, should be straightforward to compare. More complex impacts, such as those on GDP or natural capital, can be hard to separate out from other background changes. But this should not be an excuse for failing to publish simpler measures.

Commercial considerations are sometimes stated as a reason for non disclosure but these can be overblown: projects which go wrong are scrutinised in public, so it is only success stories which are not available.

Full evaluation should more often be undertaken to estimate impacts. In many areas, very few robust evaluations exist. For example, the What Works Centre for Local Economic Growth has only identified two high quality evaluations worldwide of the economic impacts of high speed rail and none for trams or cycling schemes.⁵

The Commission recommends that government should publish good quality data on infrastructure costs and performance. All public bodies taking decisions on strategic economic infrastructure should publish the forecast costs and benefits of their major infrastructure projects at each appraisal stage and at a suitable point after completion, by the end of 2019. The Infrastructure and Projects Authority should work with departments to ensure that costs are comparable between sectors.

The value of good design

Once a decision is taken, infrastructure needs to be designed and built well. This Assessment demonstrates the need for investment in the nation's infrastructure, and the Commission is committed to ensuring this is of the highest quality. Now is the time to embed design into the culture of infrastructure planning, saving money, reducing risk, adding value, supporting environmental net gain and creating a legacy that looks good and works well.

Design Task Force

In February 2018, the Commission announced a Design Task Force chaired by Commissioner Professor Sadie Morgan, to advise on how best to ensure quality design in future major infrastructure.⁶

The Task Force has concluded that achieving the Commission's design ambitions requires two things: advocacy for design at the highest level within projects and access to design expertise. Major projects, including HS2 and Crossrail already do this, embedding design in the procurement and delivery process. This approach should be adopted for all Nationally Significant Infrastructure Projects (as defined within the Planning Act 2008) and those which require Parliamentary approval. Similar arrangements should be encouraged for all other infrastructure projects. The approach could also be amplified in the Government's National Policy Statements for infrastructure.

A new independent National Infrastructure Design Group, to be established by the Commission, will develop infrastructure design principles to guide design panels, which will be published in 2019. This group will also act as a champion of design quality in the nation's infrastructure, by:

- promoting new national infrastructure design principles
- commissioning and publishing research to promote continuous improvement in infrastructure design quality
- providing inspiration and intelligence on good infrastructure design
- promoting and supporting public debate on infrastructure design.

The Commission recommends that government should be embedded into the culture of infrastructure planning, to save money, reduce risk, add value, support environmental net gain and create a legacy that looks good and works well, by:

- **Government ensuring that all Nationally Significant Infrastructure Projects, including those authorised through hybrid parliamentary bills, have a board level design champion and use a design panel to maximise the value provided by the infrastructure.**
- **Design panels for nationally significant infrastructure projects having regard to design principles to be published by the National Infrastructure Commission based on advice received from the national infrastructure design group.**

Smart, resilient design

Smart capability and resilience should form an important part of the infrastructure design process.

New data capture and processing technologies such as sensors, artificial intelligence and digital twins can generate better quality data about infrastructure, and be used to improve the way that infrastructure is planned and maintained. They can help to optimise networks, prevent failures, and better target maintenance and renewals. The Commission set out recommendations in

Data for the public good to support infrastructure becoming increasingly smart. All new projects should consider data collection and use at the design stages.

Resilience is also a key dimension in the design and management of infrastructure, including adaptation to climate change. Resilience needs to be considered both at the level of individual projects and at the level of wider systems. Individually small scale failures can multiply up in complex systems to far more serious impacts.⁷

The Commission recognised in its initial consultation on process and methodology that, given the breadth and complexity of resilience, it would not be possible to consider the issue fully in this first Assessment.⁸ The Commission intends to carry out a more in-depth analysis of resilience as a theme, working with key stakeholders, to inform a future approach ahead of the next Assessment.

Measuring infrastructure performance

Measuring the quality of the UK's current infrastructure systems can reliably inform the assessment of the UK's future infrastructure needs, and in turn enable the delivery of high quality infrastructure. Currently, the assessment of how well infrastructure is doing too often focuses on the amount of money being spent.⁹ But infrastructure has a long lifetime, and so its performance should consider the quality of service delivered by the whole infrastructure system, including its impact on natural capital. Understanding how the performance of each system changes over time could form a crucial part of the Commission's decision making in future.

The Commission intends to measure the quality of the UK's current infrastructure systems based on the framework presented in table 6.1 below. The measures in the framework work across most sectors, allowing the Commission to compare different infrastructure systems. They have also been designed to measure the performance of infrastructure against the Commission's objectives. These measures were developed following consultation on an earlier set published in the Commission's interim report, *Congestion, Capacity, Carbon: Priorities for national infrastructure*.

Table 6.1 – Performance measures

Domain	Sub-domain	Transport	Energy	Waste	Water and wastewater	Flood risk	Digital communications
Volume	Volume of consumption	Passenger/tonne km travelled (e)	Energy consumed (e)	Total waste generated (e)	Water consumed (e)	N/A	Gigabytes of data consumed (fixed and mobile) (e)
		Number of trips (e)		Residual waste generated (e)	Wastewater produced (n)		Voice minutes (fixed and mobile) (e)
Resilience	Resilience to large shocks	Stress test (n)	Stress test (n)	Stress test (n)	Security of supply index (e)	Risk of flooding and coastal erosion (e)	Stress test (n)
			Capacity margin (e)		Probability of drought (n)		
			Expected loss of load (e)				
	Everyday resilience	Travel time reliability (n)	N/A	Time that properties lose access to energy (e)	Time that properties lose access to water (e)	Number of properties flooded (n)	Number of serious incidents reported to Ofcom (e)
Quality	Service quality	Connectivity (n)	N/A	Gross value added from waste material recovery (e)	Number of water quality incidents (e)	N/A	Coverage by technology (e)
				Recycling rates (e)			Actual speed at peak time (n)
	Quality of user experience	Satisfaction derived from survey (e)	Satisfaction derived from survey (c)	Design quality (n)	Satisfaction derived from survey (e)	Design quality (n)	Satisfaction derived from survey (e)
		Design quality (n)	Design quality (n)		Design quality (n)	Design quality (n)	Design quality (n)
						Percentage of all 90-second calls completed without interruption (e)	
							Percentage of mobile data connections which deliver a speed of at least 2 Megabits per second (e)

Note: (e) denotes existing measures; (n) denotes new measures; and (c) denotes measures constructed by the Commission using existing measures

Domain	Sub-domain	Transport	Energy	Waste	Water and wastewater	Flood risk	Digital communications
Cost	Cost	Cost per passenger/tonne km (c)	Cost per kilowatt hour of energy (c) Average annual energy bill (e)	Cost per tonne of waste collected and disposed/treated (c)	Cost of water per litre (c) Cost of wastewater treated per population equivalent (c) Average annual water and sewerage bill (e)	Cost per property protected (c) Cost incurred on flood risk insurance claims (e)	Cost per gigabyte of data (fixed and mobile) (e) Average monthly bill (fixed and mobile) (e)
		CO2e emissions per passenger/tonne km (e)(c)	CO2e emissions per kilowatt hour used (c)	CO2e emissions per tonne of waste produced (c)	CO2e emissions per litre of water consumed (e) Total CO2e emission from water and wastewater (e)	N/A	CO2e emissions per gigabyte of traffic used (n) Total CO2e emissions from digital comms (n)
Environment	Emissions	Total CO2e emissions from transport (e)	Total CO2e emissions from energy (e)	Total CO2e emissions from waste (e)	Total CO2e emission from water and wastewater (e) Number of serious pollution incidents caused by water companies (e) Percentage of water bodies with unsustainable levels of abstraction (e) Average concentration of reactive phosphorus in rivers (e)	Measure of habitat improved or created (e)	N/A
		Air quality (e)	Air quality (e)	Waste generated per capita (e)			
	Environmental externalities	Noise (e)		Ground pollution from waste (n)	Value of water services provided by natural environment (e)	To be developed	To be developed
Natural capital		To be developed	Value of energy services provided by natural environment (e) Cost that energy services impose on the natural environment (e)	To be developed			To be developed
		Congestion (e)	Energy efficiency of buildings (e) Transmission/distribution losses (e) Ratio of average to peak demand (c)	Reject rates from sorting facilities (e) Capture rate of recyclable materials (e)	Leakage (e)	N/A	N/A
Efficiency	System efficiency						

Note: (e) denotes existing measures; (n) denotes new measures; and (c) denotes measures constructed by the Commission using existing measures

Details on responses to the consultation and how these informed the framework and the measures will be provided in a separate technical annex, to be published after this Assessment. The annex will also set out how the Commission intends to further develop performance measures that do not yet exist, including measures linked to natural capital (working with the Natural Capital Committee), design quality and stress tests. The measures in the framework are a work in progress and the Commission expects to update them as new measures are developed or better data becomes available.

The Commission has gathered data on many of these measures, which will also be published on the Commission's website in September 2018. This data gathering process has highlighted two significant gaps so far:

- commercial and industrial waste, where government has launched a competition to develop a new digital solution to track waste.¹⁰
- the number of properties that are flooded where data recorded by local authorities is not aggregated and published centrally.¹¹

Recommendations on filling these gaps have been set out in earlier chapters of the report.

Endnotes

- ¹ Institute for Government (2017), How to value infrastructure
- ² See National Infrastructure Commission (2017), **Congestion, Capacity, Carbon: priorities for national infrastructure**, pp.38-39
- ³ National Audit Office (2013), Over-optimism in government projects
- ⁴ Highways England (2015), Post Opening Project Evaluation (POPE) of Major Schemes
- ⁵ What Works Centre for Local Economic Growth (2015), Evidence Review 7, Transport
- ⁶ The Design Task Force was announced in the interim National Infrastructure Assessment *Congestion, Capacity, Carbon* in October 2017 and launched by Professor Sadie Morgan at the Institution for Civil Engineers in February 2018. Its members are Lucy Musgrave, Hanif Kara and Isabel Dedring. It is chaired by Commissioner Professor Sadie Morgan and advised by Tony Burton.
- ⁷ Perrow (1984), Normal Accidents
- ⁸ National Infrastructure Commission (2016), The National Infrastructure Assessment, process and methodology consultation response.
- ⁹ Institute for Government (2017), What's wrong with infrastructure decision making?
- ¹⁰ See SBRI: smart waste tracking data collection, storage and reporting services: <https://apply-for-innovation-funding.service.gov.uk/competition/175/overview>
- ¹¹ According to internal communication between the Commission and the Environment Agency.

7. FUNDING AND FINANCING



The recommendations set out in this Assessment are not simply a wish list. The recommendations are affordable within the resources set out by the government and provide a fully costed plan for infrastructure spending without significant additional costs to billpayers.

The recommendations in the Assessment have all been carefully considered by the Commission bearing in mind its objectives. The implications of the recommendations for public expenditure and for bills have been weighed up. The Commission has made judgements on priorities for expenditure within the government's infrastructure funding guidelines. In reaching its conclusions, the Commission has drawn on a wide range of evidence and considered the outcomes of its recommendations under a range of scenarios.

The cost of infrastructure services affects business competitiveness and households' quality of life. The Assessment therefore sets out recommendations to ensure that infrastructure projects are paid for at the lowest whole life cost. Efficient delivery and management of assets and good design have a part to play in this. But it also requires improvements in funding and financing arrangements:

- A UK infrastructure finance institution if the UK loses access to the European Investment Bank
- Improving the analysis of costs and benefits of private financing and traditional procurement
- Engaging stakeholders and the public on paying for road use, recognising that the existing approach is unsustainable
- Expanding and strengthening the range of mechanisms for capturing a share of increases in land value associated with infrastructure.

Paying for infrastructure

The costs of the Commission's recommendations and who will pay are included in the tables below. These set out planned infrastructure spending in the period from 2020 to 2050.

Households ultimately fund all new infrastructure. This occurs through a variety of channels. Government funded infrastructure is paid for via tax. Infrastructure paid for in this way is covered in the 'fiscal remit' table. Infrastructure funded by the private sector is paid for through bills and charges paid by households, businesses, and the public sector (for example water and gas bills). Higher costs to businesses ultimately feed through to households via the costs of goods and services. Infrastructure paid for in this way is covered in the bills table.

Fiscal remit

The government has given the Commission a long term funding guideline for public capital expenditure, the ‘fiscal remit’. 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.”¹

The fiscal remit covers capital expenditure by the public sector, including both local and national expenditure. It does not include spending by the devolved administrations, nor does it include day to day spending (‘resource’ spending).²

The fiscal remit does not only cover new projects. Existing commitments and ongoing investment in maintenance and renewals must also be accommodated alongside the Commission’s recommendations. The Commission’s remit specifically excludes consideration of decisions that have already been made, and spending that has already been committed, such as HS2. Committed spending, such as HS2; Crossrail 2 and Northern Powerhouse Rail; and maintaining current assets together add to 1.1 per cent of GDP from 2020-2025 and 0.9 per cent from 2025-2030.

Table 7.1 sets out the Commission’s proposals for the fiscal remit.

The Commission recommends that government should deliver long term certainty over infrastructure funding by adopting the funding profile set out in the ‘fiscal remit’ table in Spending Review 2019 and other future spending plans.

Bills

Households typically pay for infrastructure via bills where consumers can choose how much, or what level, of a service to purchase. For example, linking households’ energy bills to their usage helps to keep total consumption at an efficient and sustainable level.

The Commission is required to provide “a transparent assessment of the overall impact on costs to businesses, consumers, public bodies and other end users of infrastructure.”³ Table 7.2 sets out these impacts. Detailed analysis of this is included in *National Infrastructure Assessment impact and costings notes*.

Where recommendations have net costs, the Commission believes that these are manageable and good value relative to the benefits the infrastructure provides.

Table 7.1: The fiscal remit

Average annual expenditure (£ million, 2018/19 prices)	2020-2025	2025-2030	2030-2035	2035-2040	2040- 2045	2045-2050
Transport						
HS2	4,500	3,900	900			
Crossrail 2	200	2,200	2,900			
Northern Powerhouse Rail	200	1,100	1,700	1,800		
Network Rail	6,100	6,100				
Highways England	4,300	3,200				
Strategic Transport*			10,500	11,400	11,200	11,600
Devolved Cities	3,300	3,600	4,600	5,400	6,100	6,800
Transport for London	2,600	2,900	2,200	2,000	2,200	2,400
Urban Major Projects	500	400	2,400	3,100	3,500	3,900
Non-urban local transport	2,700	2,900	3,400	3,800	4,200	4,700
Local Roads Backlog		500	500			
Housing Infrastructure Fund	500	200	200	200	200	200
Energy						
Energy efficiency	100	300	300	100		
EV Charging	2**					
Digital						
Rural fibre	400	300	100			
Waste	600	500	500	500	500	500
Flood Resilience	600	700	900	1,300	1,300	1,300
Studies Contingency	300	400	400	400	400	400
Total expenditure on infrastructure	26,900	29,200	31,500	30,000	29,600	31,800
As a % of GDP	1.2%	1.2%	1.2%	1.0%	0.9%	0.8%

*combined allocation for road and rail.

**£10m funding in 2020/21.

Table 7.2: The impact on bills

Average annual aggregate impact (£ million, 2018/19 prices)	2020-2025	2025-2030	2030-2035	2035-2040	2040-2045	2045-2050
Heat trials and energy efficiency	+110	+270	+190	+180	+180	+180
Waste	+140	+110	+50	-10	-30	-60
Flood risk – lower insurance costs	-60	-240	-420	-610	-790	-980
Water – resilience to drought	+310	+640	+280	+280	+280	+280
Total impact on households, businesses and public sector	+510	+780	+100	-150	-370	-580
Total impact on households	+440	+650	+120	-60	-240	-420
Average impact per household (£/year)	+£20	+£20	£0	£0	-£10	-£10
Total impact on businesses	+50	+90	-20	-70	-100	-130
Total impact on public sector resource spending	+20	+40	0	-20	-30	-30

Impacts are shown relative to a baseline without the recommendation. This is different to the energy bills impacts described in the *Low Cost, Low Carbon* chapter which compare 2050 to today. Negative figures denote savings. Columns may not sum to totals due to rounding

The Commission's choices

The recommendations in this Assessment, and the implications for public expenditure and for bills, reflect the judgement of the Commissioners. In reaching its conclusions, the Commission has drawn on a wide range of evidence, including scenario based modelling, stakeholder expertise and opinions, social research, and specially commissioned studies (which are available on the Commission's website). Further details on the Commission's approach are set out in *The National Infrastructure Assessment: process and methodology* and the interim report *Congestion, capacity, carbon: priorities for national infrastructure*.

Meeting the Commission's objectives

These recommendations reflect the Commission's objectives: to support sustainable economic growth in every region; improve competitiveness; and improve quality of life.

Sustainable economic growth in every region: Full fibre digital infrastructure and urban transport networks lower the costs of connecting firms, workers and consumers; capture the benefits of higher productivity in dense clusters of firms; and enable innovation.

International competitiveness: Low cost energy supports international competitiveness as an input to all economic activity. Promoting electric, connected and autonomous vehicle infrastructure supports the UK motor industry to stay at the forefront of innovation.

Quality of life: Better air quality from electric vehicles, warmer homes from energy efficiency and a better designed public realm can improve people's quality of life. Resilience to floods and droughts protects people against natural disasters.

Prioritising within the fiscal remit

Resources are inevitably limited. This has required the Commission to prioritise between available options in some areas.

Prioritise support for new infrastructure networks in the short term:

Broadband and electric vehicle charging have been prioritised in the short term, when resources are most constrained. These new technologies represent major opportunities for growth and are particularly time critical if the UK is to remain internationally competitive.

Prioritise urban transport over intercity networks in the 2030s: Most spending on major upgrades to urban infrastructure, recommended in Chapter 4, will come in the late 2020s and especially in the 2030s. This profile reflects the overall availability of resources, as well as the need for local capability and for proposals to be developed by cities. In later years, urban spending will be balanced by reduced spending on major enhancements on the intercity networks, which will have seen at least a decade of sustained high investment.

Focusing on low regret options on the motorway and major road network while the impact of new technology is uncertain: Figure 7.1 sets out the enhancement budget for Road Investment Strategies 1 to 3, together with historic estimates of equivalent spending in the past. For future Road Investment Strategies, maintenance, renewals and incremental enhancements should be prioritised over 'mega projects' given the increased uncertainty that new technology creates for projects with very long payback periods. Large road and rail projects should compete for the same funding, as indicated in the fiscal remit table, to ensure the most beneficial projects are taken forward regardless of mode. An additional £500m a year should be spent on basic maintenance for local roads between 2025-2035.

Balance increased rail expenditure in the late 2020s with other priorities:

There is a major increase in rail expenditure in the 2020s from HS2, Northern Powerhouse Rail and Crossrail 2, as shown in figure 7.2. Continuous change is not sustainable for the rail network and there are other priorities; sums for further enhancements in Network Rail in the late 2020s ('Control Period 7') should be correspondingly lower, although funding for maintenance and renewals should be protected.

Provide an indicative budget for Northern Powerhouse Rail of £24 billion from 2023-24 to 2039-40: The business case for Northern Powerhouse Rail remains under development. It is important that Transport for the North sets its priorities for the region and a clear budget will allow that to happen. However, city leaders in the region should have the freedom to shift additional funding from urban budgets to Northern Powerhouse Rail if they choose.

Provide an indicative budget for Crossrail 2 of £27.7 billion from 2023-24 to 2035-36: In line with *Transport for a world city*,⁴ this reflects the need for Transport for London to reduce and phase the costs of the scheme. London should contribute at least half of the scheme costs.

Provide a gradual increase in the budget for flood protection: This reflects the long term strategy proposed in Chapter 5. Spending is weighted towards later years due to other priorities in the 2020s and the time needed for the development of robust plans to achieve the required level of protection.

Apply efficiency savings to renewals spending: These are in line with the government's *Transforming Infrastructure Performance*⁵ productivity programme.

Maintain the Housing Infrastructure Fund outside cities: Within cities, this funding should be merged into wider devolved funding for strategic transport and housing strategies.

Leave headroom in the later period: Some recommendations, such as flood protection, involve spending to 2050. But overall there is considerable space in later years. This will be needed for future priorities such as zero carbon heat, surface water flooding or even completely new infrastructure that may be needed in decades to come.

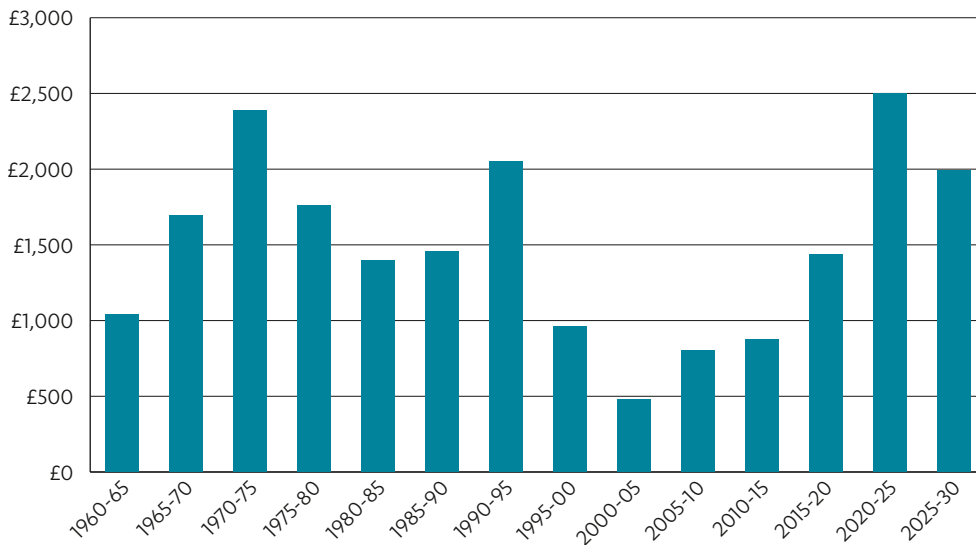


Figure 7.1: Historic and planned enhancement spending on strategic roads⁶

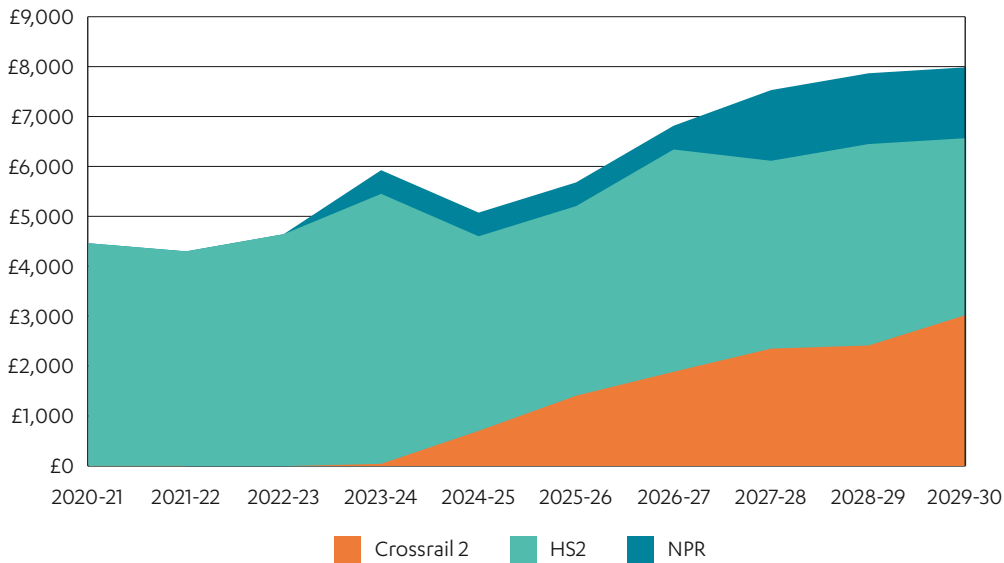


Figure 7.2: Capital Investment in rail ‘mega projects’ (£m, 2018/19 prices)

Managing uncertainty

The Commission has also considered how the impact of its recommendations may be affected by uncertainty, focusing particularly on technology, population, economic growth and climate change.⁷ The Commission has sought to understand how robust its decisions would be to uncertainty, seeking solutions that will stand the test of time, but recognising that some uncertainty is unavoidable given the timescales for infrastructure investment.

Balancing the risks of major investments: For full fibre and water, the potential costs of inaction are much higher than those of action. For flood protection, a more ‘adaptive’ approach can be taken because defences can be added to incrementally if risks turn out higher. For energy, the Commission’s judgement is that the supply chain for nuclear power should be maintained by agreeing a further plant beyond Hinkley Point C, even though renewables look like an increasingly viable alternative, as the costs of re-establishing the nuclear supply chain would be very high.

Making complementary recommendations: Investing in both urban transport and rural fibre mitigates uncertainty about the future location of economic activity. Electric vehicle charging helps reduce the cost of more renewables intensive electricity generation by providing more flexible demand and potentially lowering the cost of storage.

Planning for future decisions: Investing in renewables in the 2020s will improve understanding of system balancing costs for the 2030s and 2040s. Separation of food waste is good value for money today, but also maximises the availability of biogas. Biogas has a range of potentially high value uses replacing hard to substitute fossil fuels in future. Assessing the potential impact of connected, autonomous vehicles on road and rail investment could reduce the risk of costly long term investments being overtaken by technology.

Strategic use of public and private financing

Infrastructure typically requires large up front investment ('financing') followed by a long period in which these costs, plus on going maintenance and operational costs, are repaid by users or taxpayers ('funding'). The Commission's recommendations will require a combination of public and private financing mechanisms and these arrangements should be as efficient and as cost effective as possible.

Finance itself is not in short supply.⁸ However, in some cases public sector support can ease constraints on the financing of projects in the private sector. In other cases, private finance could increase the efficiency of projects in the public sector and share risks.

UK infrastructure finance institution

The UK has a high proportion of privately owned, operated and financed infrastructure.⁹ Almost half of the planned pipeline of infrastructure projects to 2020/21 will be delivered and funded privately.¹⁰ It has well developed capital markets which generally help to facilitate this private finance. And there is an appetite on the part of institutional investors to increase both the scope and scale of their investment in infrastructure projects.¹¹

Both government and arms length independent state institutions can help to support this investment, by absorbing risk that the market finds hard to manage and supporting due diligence functions for innovative projects. The government already has some established mechanisms to support private investment such as the UK Guarantee Scheme.

There is an ongoing market failure around innovation in the infrastructure sector; the risks associated with innovative technologies, techniques and financial products can be too high for the private sector without government support.¹² For example there is strong evidence that the Green Investment Bank helped to catalyse private investment in offshore wind.¹³ And there is a role for government in easing liquidity constraints in the infrastructure market during times of crisis.¹⁴

Independent financing institutions can mitigate some of the risks involved in public sector support for private investment. Independent institutions can provide policy stability in areas which exist outside of the short term political cycle. They can also develop expertise and credibility, which can be used to build the understanding and capabilities of both private investors and local government.¹⁵ A portfolio of investments allows an institution to take risk without imposing an overall cost on the public purse.

In the past, the European Investment Bank and the recently privatised Green Investment Bank have provided this kind of function in the UK.¹⁶ The government has indicated that it may be mutually beneficial to maintain a relationship between the UK and the European Investment Bank¹⁷, and the Commission

has heard from a wide range of stakeholders that this would be their preferred outcome. However, it may not be possible: a contingency plan is needed.

Any new domestic institution would not score within the Commission's fiscal remit, since its activities would score as 'financial transactions' rather than as capital expenditure. However, unlike the European Investment Bank, lending by any domestic institution would score within the government's main debt measure, Public Sector Net Debt.¹⁸ A new institution would therefore need a clear remit, and robust processes, to ensure additionality and 'sound banking' (measuring project returns in terms of risk adjusted interest rates and lending at market rates).¹⁹

The Commission recommends that government should maintain access to the European Investment Bank if possible. If access is lost, a new, operationally independent, UK infrastructure finance institution should be established by 2021. To enable this, government should consult on a proposed design of the new institution by Spring 2019. The consultation should cover:

- **Functions, including provision of finance to economic infrastructure projects in cases of market and coordination failures; catalysing innovation; and acting as a centre of excellence on infrastructure project development, procurement and delivery**
- **A clear mandate, including sound banking, additionality and having a wider economic and social impact**
- **Governance to safeguard the operational independence of the institution.**

Evaluating the performance of private financing and traditional procurement

As well as the public sector supporting private financing, private finance can support public sector projects. The introduction of private financing into public infrastructure delivery came following a poor record of public sector delivery.²⁰ It has led to quicker delivery of projects, enabling society to access infrastructure services earlier, and contributed to better public sector commercial capability.^{21,22}

Private financing, in comparison to traditional procurement, encourages a whole life approach to project design. The transfer of risk to the private partner incentivises efficiency in delivery over the project lifecycle but can sometimes create challenges where requirements change during the project lifetime. There is a residual level of risk that can never be transferred, since in extreme circumstances projects can return to the public sector where private providers go bankrupt.

There has been a slowdown in the use of private financing in recent years due to uncertainties about its cost effectiveness and the rationale for its use.²³ The overall performance of private finance has not been robustly evaluated.²⁴

The Commission proposes an analytical framework for whole life analysis of the costs and benefits of private financing and traditional procurement, set out in the technical annex *Proposed analytical framework for evaluating the performance of private financing and traditional procurement*. It builds on past studies considering performance and costs during construction by covering the whole lifespan of projects and a wider range of potential benefits.

Consultation has found a wide consensus on the dimensions in the framework. The immediate next steps are for the framework to be piloted to develop insights on its practical application and identify where it needs to be revised.

Following the pilot, the Commission aims to develop a consistent evidence base of costs and benefits of financing models through more detailed analysis. This independent source of evidence should lead to the more strategic use of private financing and traditional procurement, and improve the design of existing models to build more collaborative long term approaches.

Additional funding mechanisms

Paying for road use

Road use is a notable exception to the general principle that infrastructure is paid for through bills where consumers can choose their level of usage.

Over the Assessment's timeframe changes to the way drivers pay as they use roads are inevitable. Fuel duty revenues will decline with the impending shift to electric vehicles.²⁵ Technological change has the potential to radically change driving patterns and vehicle ownership. The current system of road taxation is not sustainable.

One option might be to introduce a 'road pricing' scheme to charge drivers according to where and when they drive, which could deliver valuable benefits. Road pricing can:

- Pay for new and better road infrastructure; creating a revenue stream from roads can attract private investment, as with some toll roads
- Reduce congestion; congestion is estimated to cost the economy over £35 billion a year, and pricing congestion has been shown to reduce traffic volumes^{26,27}
- Protect tax revenue; fuel duty will decline and road pricing is a sustainable alternative

The changing use of roads presents an opportunity to design a road pricing scheme that improves on current road taxation by being fairer, more sustainable and more effective at reducing the negative impacts of driving. Developments in technology provide new ways to implement road pricing that have previously been too expensive or impractical. Some possible changes, such as 'mobility

as a service', where people pay for journeys rather than car ownership, would naturally fit with alternative forms of road pricing.

There has often been a disconnect between theoretically perfect road pricing systems suggested by policymakers and the perceived fairness and practicality of those systems by the public.²⁸ Rather than propose a further technocratic recommendation the Commission will explore new ways to engage stakeholders and the public on this topic, looking at a full range of potential options in light of the major changes in road use and taxation that are inevitable. Reforming how road use is paid for has been discussed for decades,²⁹ but the issue is becoming more and more pressing and cannot be avoided forever.

Land value capture

Local funding for infrastructure can strengthen local accountability, sharpen the incentives for scheme designers to maximise local benefits, and improve the fairness of the funding regime as local beneficiaries contribute to the scheme costs. One approach to raising funding locally is to capture part of any increase in land values from infrastructure development or planning permission for new developments. But the Commission's analysis suggests this is not the silver bullet for funding local infrastructure.³⁰

Whilst the current system, comprising Section 106 contributions from developers and the Community Infrastructure Levy, is complex, it is more successful at raising funding than previous approaches.³¹ Other parts of the tax system, such as Capital Gains Tax and Stamp Duty, also capture a proportion of land value increases, although there are no reliable measures of how much. Some have argued for radical reform of local funding.³² However, without a full picture of existing receipts it is unclear this would increase total revenues, and the history of previous reforms argues for caution.³³ Reform would undoubtedly lead to costs and delays in the short term as land owners and developers sought to understand new liabilities before making major decisions.

The sums potentially available would vary significantly across the country. Analysis undertaken for the Commission indicates that roads investment which reduces travel times by 10 per cent in the Cambridge – Milton Keynes – Oxford Growth Arc is associated with higher average property values of over £3,000 per property; a similar scheme in the East Midlands is associated with higher values on average of £2,000 per property and in Yorkshire of £1000 per property.³⁴

The Commission's remit covers the interaction between infrastructure and housing, but not housing itself. The Commission has therefore looked at local funding mechanisms from the perspective of infrastructure funding and has concluded that the existing system should be improved rather than replaced, identifying three policies to help raise local revenues.

Business rates and council tax

London used a business rate supplement to help fund Crossrail 1.³⁵ This supplement, charged at 2p for every £1 paid by businesses above a certain threshold, will eventually provide nearly one third of Crossrail 1's costs. Applying a small charge to a large base of rate payers is a simple way to gather a contribution to scheme costs. The same approach could be applied to council tax, where a precept could be applied to reflect part of the increase in property values that result from new transport infrastructure.³⁶ To protect existing residents, the precept could be applied only to new residents that move into the area. To ensure the precept is genuinely related to project costs, it could be time-limited.

Changes in the 2011 Localism Act now require a majority of business rate payers to agree to the supplement, both in number of rate payers and by the value of the rates paid.³⁷ This is difficult to coordinate; introducing a threshold of one third of scheme costs before ballots are used would make the funding tool simpler to use while retaining safeguards. In this way, future infrastructure projects could benefit from Crossrail 1's innovative funding structure.

Community Infrastructure Levy

The government are currently consulting on changes to improve the Community Infrastructure Levy. Pooling section 106 agreements across several projects was an important means for local authorities to develop bespoke funding solutions such as the Milton Keynes Tariff. However local authorities are currently not allowed to do this.³⁸ The government's proposals would remove pooling restrictions in some but not all cases, which would create further complexity and limit flexibility. A simpler approach would be to remove all pooling restrictions which would allow local authorities to use section 106 more effectively.

Compulsory purchase regime

The compulsory purchase regime, whereby local authorities can buy land as a last resort, could be strengthened. The current regime is costly, time consuming and uncertain.³⁹ Conducting an independent assessment of site value at the start of the process could save money and provide more certainty for the parties involved in a compulsory purchase order.

The Commission recommends that local authorities should be given further powers to capture a fair proportion of increases in the value of land from planning and infrastructure provision. To enable this, government should:

- Remove pooling restrictions on Section 106 in all circumstances, through forthcoming secondary legislation by 2020
- Remove the ballot requirement for upper tier authorities' powers to levy a business rate supplement of 2p or less in the pound for infrastructure, except where the supplement exceeds one third of scheme costs by 2021

- Give local authorities powers to levy zonal precepts on council tax, where public investments in infrastructure drive up surrounding property values by 2021
- Provide greater certainty in compulsory purchase compensation negotiations by including independent valuations early in the process to be paid for by the acquiring authority by 2021.

Endnotes

- ¹ HM Treasury (2016), National Infrastructure Commission Remit letter
- ² Further details are set out in the Charter for the National Infrastructure Commission, the Government's Remit letter for National Infrastructure Commission of 23 November 2016 and in the Commission's interim report Congestion, Capacity, Carbon: Priorities for national infrastructure
- ³ HM Treasury (2016), National Infrastructure Commission Remit letter
- ⁴ National Infrastructure Commission (2016), Transport for a world city, converted to 2018/19 prices
- ⁵ Infrastructure and Projects Authority (2017), Transforming infrastructure performance
- ⁶ Historic data from Department for Transport (2014), Road Investment Strategy: Strategic Vision, 2013/14 prices
- ⁷ The Commission has published discussion papers on each of these topics, which are available on the Commission's website
- ⁸ Cambridge Economic Policy Associates (October 2017), Financing for infrastructure summary report
- ⁹ Eunomia Consulting (2018), Comparative Study of National Financing Institutions – commissioned by the National Infrastructure Commission
- ¹⁰ Infrastructure and Projects Authority (2017), Analysis of the National Infrastructure and Construction Pipeline
- ¹¹ Pensions Infrastructure Platform (2018), Response to Congestion, Capacity, Carbon
- ¹² HM Government (2011), Update on the design of the Green Investment Bank
- ¹³ Vivid Economics (2018), The role and impact of the EIB and GIB on UK infrastructure investment
- ¹⁴ Ibid
- ¹⁵ LSE Growth Commission (2013), Chapter IV: Investment in Infrastructure, LSE Growth Commission Report (2013), Investing for Prosperity – Skills, Infrastructure and Innovation; Vivid Economics (2018), The role and impact of the EIB and GIB on UK infrastructure investment
- ¹⁶ Vivid Economics (2018), The role and impact of the EIB and GIB on UK infrastructure investment
- ¹⁷ Mansion House 2017: Speech by the Chancellor of the Exchequer, 20 June 2017
- ¹⁸ ONS (2017), Wider measures of public sector liabilities. As a public corporation, a domestic institution would not score within the more widely used international measure of General Government Gross Debt. The government has also introduced a new measure, Public Sector Net Financial Liabilities, which would more accurately reflect the impact of any new institution on overall fiscal risk, by including both assets and liabilities.
- ¹⁹ 'Additionality' and 'sound banking' are two of the three core lending principles used by the European Bank for Reconstruction and Development. See: Besley, Dewatripont and Guriev (2010), Transition and transition impact: A review of the concept and implications for the EBRD, Report for the EBRD's Office of the Chief Economist
- ²⁰ National Audit Office, Modernising Construction HC-87, Session 2000-01
- ²¹ Romboutsos, (2016), Public Private Partnerships in Transport Infrastructure, Transport Reviews and Boardman, et al (2015), Comparative Analyses of Infrastructure Public Private Partnerships
- ²² The Allen Consulting Group (2007), Performance of PPPs and Traditional Procurement in Australia; Makovsek (2013), Public – Private Partnerships, Traditionally Financed Projects, and their Price, Journal of Transport Economics and Policy
- ²³ National Audit Office (2018), PFI and PF2
- ²⁴ Ibid
- ²⁵ National Infrastructure Commission (2017), Congestion, Capacity, Carbon: Priorities for national infrastructure
- ²⁶ Cookson, INRIX Research (2018), INRIX Global Traffic Scorecard
- ²⁷ Transport for London (2007), Central London Congestion Charging Scheme: ex-post evaluation of the quantified impacts of the original scheme
- ²⁸ RAC Foundation (2011), The Acceptability of Road Pricing https://www.racfoundation.org/wp-content/uploads/2017/11/acceptability_of_road_pricing-walker-2011.pdf
- ²⁹ Ibid
- ³⁰ Institute for Fiscal Studies (Forthcoming), Property Value Uplift Tool
- ³¹ Crook, T., Henneberry, J., Whitehead, C. (2012), Planning Gain – Providing Infrastructure and Affordable Housing, Wiley Blackwell
- ³² Centre for Progressive Policy (2016), Bridging the infrastructure gap
- ³³ Ibid
- ³⁴ Institute for Fiscal Studies (Forthcoming), Property Value Uplift Tool
- ³⁵ Greater London Authority (2018), Crossrail Business Rate Supplement 2018/9 ratepayer leaflet
- ³⁶ Transport for London (2017), Land Value Capture
- ³⁷ The Localism Act (2011)
- ³⁸ National Infrastructure Commission (2017), Partnering for Prosperity, and Regulation 123 of the Community Infrastructure Levy Regulations 2010
- ³⁹ Compulsory Purchase Association (2017), Annual Law Reform Lecture 2017 pre-event reading material, available at: <http://www.compulsorypurchaseassociation.org/cpa-law-reform-lecture-2017.html>

8. NEXT STEPS



This is the Commission's first Assessment of the UK's economic infrastructure. Since its establishment, the Commission has been working to identify the key priorities for the nation's infrastructure, culminating in the recommendations set out in this Assessment. But the work does not stop here. These recommendations need to be implemented. Government, regulators, industry and others will all need to contribute to making this a reality. The Commission will report on progress in its Annual Monitoring Report. And the second Assessment, expected in around 5 years' time, will develop on these themes and identify future priorities for the UK's infrastructure.

Over the coming months and years, the Commission will:

- seek consensus on its recommendations
- work with government to establish its recommendations as government policy
- monitor the implementation of the recommendations set out in the Assessment alongside those in its earlier studies
- carry out further work on some of the areas outlined in this Assessment, including housing, design and economic regulation
- begin work on the second National Infrastructure Assessment, expected around 2023.

Consensus building

Too often in the past, a lack of political consensus has led to delays and extra costs in infrastructure. The Commission was established to provide independent advice and analysis and to move away from a position where the main promoters of infrastructure are either politicians or scheme developers, whose arguments, however well made, are often treated with scepticism. Ultimately, it is for government to decide on the Commission's recommendations. However, over the coming months, the Commission will endeavour to build consensus around its recommendations and engage across parties and with the public, policy makers, infrastructure experts and relevant bodies, as set out in its framework document.

As set out in the Executive summary, the Commission's remit extends to economic infrastructure within the UK government's competence, and will

evolve in line with devolution settlements. This means the Commission's recommendations will apply to non devolved UK government infrastructure responsibilities in Scotland, Wales and Northern Ireland (and all sectors in England). The Commission will continue to engage closely with devolved administrations and bodies under their jurisdictions as appropriate, particularly on matters where the respective infrastructure policy responsibilities of the UK government and devolved administrations interact.

Government response

The Commission's framework document states that:

"The government will lay the [Commission's] reports before Parliament, and will respond to the [Commission's] national infrastructure assessment and specific studies. The government will respond as soon as practicable; it will endeavour to respond within 6 months, and not longer than a year. The response will set out clearly any further work required to take forward the recommendations. Recommendations the government agrees should be taken forward will become known as 'endorsed recommendations'. Where the government does not agree with a Commission recommendation, it may put forward an alternative proposal.

"Where the government is responsible for delivering endorsed recommendations, the government's endorsement will be a statement of government policy. Where recommendations have wider implications for the planning regimes, the government will highlight any further steps needed to confirm the endorsed recommendation as planning policy. The government will use the levers at its disposal to deliver endorsed recommendations – whether through spending, regulation, deregulation, market stimulation, or by setting strategic priorities for regulators as appropriate. In some cases, endorsed recommendations will not be directly taken forward by the government, but may be relevant for decisions made by other bodies such as economic regulators."

The Commission will provide support to government as it makes its decisions on the Assessment's recommendations, including as it prepares for the forthcoming Budget and Spending Review, to ensure that the analysis and conclusions in the Assessment are fully understood and any questions are answered accurately.

Monitoring

The Commission has been established as a permanent, independent body, and so has a role in holding the government to account for implementing its recommendations, where they have been agreed. The Commission's framework document states that "the [Commission] will hold the government to account for delivering [Commission] recommendations that the government has endorsed and agreed to take forward."

The Commission will monitor the government's progress in delivering endorsed recommendations, and will comment on this in its Annual Monitoring Report.

Where the recommendations have implications for other bodies, such as economic regulators, the Commission will also comment on the progress made by the relevant bodies.

Further work

The Commission has set out an ambitious set of recommendations in this Assessment. However, in some areas there is still further work to do. Alongside its study programme, which is currently focusing on the future of the UK's freight network, the Commission has identified the following priorities for further work:

- developing the Commission's work on the link between infrastructure and housing
- developing further the work of the design task force to champion design quality in the nation's infrastructure
- addressing the evolution of the regulatory framework and its adaptability to different models of utility service provision
- continuing development of the ideas generated by the Commission's 'Roads for the Future' innovation competition, which concludes in September
- continuing to develop the Commission's performance measures, both by filling gaps – including establishing measures linked to natural capital, design quality and resilience – and by progressively updating the measures set out in Chapter 6 as new approaches are developed or better data becomes available
- continuing work on cost benefit analysis, including developing alternative approaches where current methods perform less well
- developing the analytical framework for the performance evaluation of public private partnership projects.

The Commission also intends to work with a small number of urban authorities to explore how the national strategies set out in this Assessment could inform long term infrastructure planning for cities and city regions.

The second National Infrastructure Assessment

The Commission publishes an Assessment once every five years. Work on the next Assessment will begin as soon as the first is published.

Given that this kind of cross-sector assessment has not been undertaken at a national level before in the UK, as a first step the Commission will carry out a 'lessons learnt' review shortly after the publication of the Assessment, informed by stakeholder views.

Drawing upon the outputs from this review, the Commission will prepare the process and methodology for the next iteration of the Assessment, on which it expects to engage with stakeholders before carrying out a public consultation. Alongside this, it will develop its evidence base and identify the key areas for further research and analysis.

An important priority will be to undertake more in-depth analysis of infrastructure resilience, as previously indicated in the Commission's Process and Methodology consultation.¹ In addition, a number of other areas have been identified, which the Commission will return to in its next Assessment, in the light of developing evidence and technology. They include: the future of heat, as set out in Chapter 2; a national transport strategy that considers the potential changes to travel patterns by road and rail as connected and autonomous vehicles become more widespread, discussed in Chapter 3; the use of data in improving the performance and planning of infrastructure as data is becoming part of infrastructure; surface water, building on the joint plans to manage surface water flood risk to be developed by local authorities and water companies, covered in Chapter 5; and paying for road use, where the Commission will explore new approaches to public engagement to identify options which are fair, sustainable and reduce the negative impacts of driving, covered in Chapter 7.

The second Assessment is expected to be published around 2023.

Endnotes

¹ National Infrastructure Commission (2016), National Infrastructure Assessment: Process and methodology consultation

Annex A: Glossary

Term	Meaning
1. Building a digital society	
4G	Fourth generation of mobile systems. 4G provides faster data speeds than previous generations.
5G	The fifth generation of wireless networks beyond 4G mobile networks. 5G is expected to deliver even faster data rates and better user experience, although international standards have not yet been set.
Anti-competitive behaviour	Strategies designed to limit and prevent fair competition, for example predatory pricing and collusion.
Augmented reality	Augmented reality is a technology that overlays computer generated enhancements on the real world.
Broadband	A type of high speed internet connection.
Capital costs or expenditure	Fixed one-time expenses that are incurred upfront, usually when paying for assets such as buildings, construction or equipment (ongoing costs are usually referred to as operational costs).
Clawback mechanism	A special contractual clause which allows money that has already been spent to be paid back under certain conditions.
Connected and autonomous vehicles (CAV)	Connected vehicles can communicate with their surrounding environment. Autonomous vehicles can operate with little or no human input (be driverless) for some, or all, of the journey. Connected and autonomous vehicles can do both.
Deregulation	Deregulation is the removal of regulation, usually with the aim of increasing competition and innovation.
Digital economy	The digital economy refers to the economic activity that is based around digital technologies.
Ducts	A tube or passageway to hold cables, usually underground.
Economic regulation	Economic regulation applies the principles of competitive markets to network industries to achieve greater efficiency and to move away from monopolistic outcomes.
Fair bet	This is a regulatory principle which recognises that an investing firm needs to benefit from sufficient upside potential from any investment to offset the downside risk of failure. The regulator should only impose regulation once a 'fair' return has been made.

Term	Meaning
Gigabit speeds	Download speeds above 1000 megabits per second. 1 gigabit is 1,000 megabits.
Megabits per second (Mbps)	A measure of the rate at which data can be transmitted. One megabit per second is 1 million bits per second (bps). One bit is a single binary digit: 1 or 0
Mobile coverage	The geographic area covered by mobile services.
Openreach	Openreach is the UK's telecoms incumbent network operator. It owns, operates and maintains the UK's main broadband and landline network.
Operating costs or expenditure	Day-to-day spending on running services and maintenance.
Reasonable cost threshold	A reasonable cost threshold is the cost limit at which government will subsidise up to. The costs above this threshold are not deemed reasonable or fair to impose upon taxpayers or billpayers.
Superfast broadband	Broadband services that deliver download speeds of at least 30 megabits per second (mbps).
Ubiquitous connectivity	Digital connectivity everywhere.
Virtual reality	Virtual reality (VR) is an artificial, computer-generated and immersive simulation usually through a headset.
WiFi	A wireless connection which allows devices to connect to the internet.

2. Low cost, low carbon

Balancing	The processes and systems required to balance supply with demand in the electricity system. A range of technologies can provide balancing services.
Biogas	A gas produced by breaking down organic matter in the absence of oxygen. This gas can be used in a similar manner to natural gas to produce heat or electricity but unlike natural gas, biogas from sustainable sources is a renewable fuel.
Biomass	A renewable fuel of organic material, such as wood, plants or other waste. Biomass can be burned directly or processed into biofuels such as ethanol and methane.
Black bag waste	Black bag waste is household items which cannot be recycled.
Capacity market	In the capacity market the government determines what level of system security is required for four years ahead and then commissions National Grid to calculate the amount of generating capacity that would deliver this. National Grid then runs an auction to procure this capacity at the lowest price.
Carbon capture and storage (CCS)	A process to capture, transport and store carbon dioxide emissions from fossil fuel use. It prevents the carbon dioxide from entering the atmosphere, usually by storing it underground.

Term	Meaning
Climate Change Act	The Climate Change Act, established in 2008, sets legally binding targets to reduce carbon dioxide emissions in the UK by at least 80% by 2050, from 1990 levels.
Decarbonisation	Decarbonisation refers to the removal or reduction of carbon dioxide (a greenhouse gas) from energy sources with the purpose of reducing the impact of climate change.
Deposit Return Scheme	Consumers pay a deposit for an item, such as a single use drink container, which is redeemed on return of the item.
Digestate	Digestate is the solid residue left over from anaerobic digestion which can be used as fertilizer.
Distribution of electricity	The lower voltage (as compared with the transmission of electricity), local, electricity network which is used to deliver electricity to most customers.
Electric vehicle	For the purposes of this report, 'electric vehicles' refers to fully electrified plug-in vehicles that run entirely from an electric battery that must be recharged. This is distinct from hybrid and plug in hybrid vehicles which have both a conventional and an electric motor.
Energy Performance Certificate level C	An Energy Performance Certificate is required for properties when constructed, sold or let. It provides details on the energy performance of the property and what can be done to improve it. The levels range from A-G, A is the most energy efficient whilst G is the least energy efficient.
Energy system	The energy system is the combination and interaction of supply and demand for energy. Energy is used for a range of different activities, such as: transport, heating and powering homes and in industrial processes. Energy is created from a variety of sources including renewables, fossil fuels and nuclear.
Fossil fuel	Fossil fuels are hydrocarbons formed in the earth from biological origin such as coal, oil and natural gas. They are non-renewable and produce greenhouse gases when burnt for energy which cause global warming.
Gasification	Gasification is a process of converting biomass and waste into fuel. It uses little or no oxygen to convert carbon-based materials into synthetic gas which can be used to generate electricity or in place of natural gas.
Greenhouse gas emissions	Greenhouse gases trap heat in the atmosphere which leads to global warming and climate change. Carbon dioxide is the most prevalent of the greenhouse gases and is emitted from activities such as burning fossil fuels.
MW, GW, TW	A watt is a unit of power, which quantifies the rate of energy transfer. A megawatt (MW) is 1,000,000 watts, a gigawatt (GW) is 1,000 megawatts and a terawatt (TW) is 1,000 gigawatts.

Term	Meaning
MWh, GWh, TWh	A watt hour is a measure of energy. It is equal to the total energy delivered by a rate of energy transfer of one watt, provided for one hour. A megawatt hour (MWh) is 1,000,000 watt hours. A gigawatt hour is 1,000 MWh and a terawatt hour is 1,000 gigawatt hours (GWh).
Incinerators	Facilities in which waste is burned in a controlled fashion, either to reduce its volume or its toxicity. Energy from waste plants use incineration of waste to generate electricity, and in some cases heat for domestic or industrial heating.
Interconnector	Electricity interconnectors are physical links which allow the transfer of electricity across country borders. Britain's electricity market currently has links with France, the Netherlands, Northern Ireland and the Republic of Ireland.
Landfill	Area of land where waste is disposed of, either on top or buried.
Load factors	The load factor is the ratio of total energy used in a period to the maximum possible energy use in that period.
Natural gas	Natural gas is a fossil fuel used as a source of energy for heating, cooking, and electricity generation. It is mainly composed of methane, which burns to give carbon dioxide and water vapour.
Nuclear power plant	Power plants make electricity. A nuclear power plant does this through nuclear reactions relying upon uranium (a non-renewable energy source). Nuclear power plants do not emit greenhouse gases but they do produce radioactive waste.
PET	PET (polyethylene terephthalate) is a very common plastic widely used for packaging food and drinks.
Power generation	Power generation refers to the creation of electricity.
Power station	A power station is where electricity is generated.
PVC	PVC (polyvinyl chloride) is a very common plastic used in packaging.
Pyrolysis	The burning of waste in a controlled (oxygen-depleted) environment to generate a combustible gas (syngas).
Recycling	The process of converting waste into reusable material.
Renewable energy	Renewable energy is generated from natural resources, such as sunshine and wind.
Small modular reactor	Small modular reactors generate electricity by a nuclear reaction. These reactors are smaller than conventional nuclear reactors, with power outputs of around 300 MW compared to around 1000 MW or more. No small modular reactors are currently in commercial operation.
Tidal lagoon	A tidal lagoon is a power station which generates tidal power. It is an enclosed area of coastline with a high tidal range which drives turbines and generates electricity.

Term	Meaning
Tidal power	Tidal power is the production of electricity using the ocean's tide. It is a renewable and predictable source of energy.
Transmission of electricity	The high voltage electricity network, used to move electricity long distances across the country.
Wholesale market	Great Britain has a liberalised electricity wholesale market where prices are not set by a regulator. The wholesale market is where retail suppliers, traders and large consumers purchase energy in bulk from those that the generate energy.

3. Revolutionising road transport

Centre for Connected and Autonomous Vehicles (CCAV)	The organisation which works across government to support the market for connected and autonomous vehicles.
Charge point	A charge point is the infrastructure which supplies the electricity to recharge electric vehicles.
Control Period 6/7	Network Rail, which owns and operates the railway infrastructure in England, Wales and Scotland, has 5-year 'control periods' to decide investment priorities. Control Period 6 and 7 refer to the periods 2019/20-2023/24 and 2024/25-2028/29 respectively.
Freight	Freight is the term used to define the transportation of goods rather than people.
Hybrid vehicle	A hybrid vehicle is one which uses two different energy sources, such as petrol or diesel with electricity.
Internal combustion engine vehicle	An internal combustion engine vehicle is a conventional vehicle which runs by burning a fuel, usually petrol or diesel, inside the engine.
Interoperable	Interoperability refers to the ability of a product or system to operate with other products or systems without any restrictions.
National Grid	A British multinational electricity and gas utility company whose operations include owning and operating electricity transmission network assets and part of the national gas grid
Rapid chargers	Rapid charge points, of 43kW or above, can charge an electric vehicle battery in 20-30 minutes. Some 'fast' chargers, of 22kW, can charge current models of electric vehicle in about an hour.
Road investment strategy (RIS)	The government's investment plans for 5 year periods for the Strategic Road Network of 4,400 miles of motorways and major 'A' roads managed by Highways England. Road investment strategy 1 covers 2015/16-2019/20; Road investment strategy 2 will cover 2020/21 to 2024/25.

Term	Meaning
S-shaped diffusion curve	The diffusion of an innovation is said to follow an S-shaped curve. This involves three phases: slow initial uptake by a few early adopters; uptake rapidly increases as the innovation gains popularity and finally; uptake slows down and levels off as the innovation reaches maturity.
Vehicle to grid	Vehicle to grid systems involve electric vehicles returning power, stored in car batteries, to the electricity grid at peak times.
4. Transport and housing for thriving city-regions	
Brownfield	Brownfield land refers to urban sites that have had previous developments on them but are now vacant, derelict or contaminated.
City	Cities are large urban areas. There is no single definition in use in the UK. Generally, the Assessment uses the 'primary urban area' definition originally established for the State of the English Cities report. Under this definition, there are 63 cities in the UK. This equates to cities with a population of around 110,000 or larger. 'Major cities' refers to the largest UK cities, with a population of around 500,000 or larger (Birmingham, Bristol, Glasgow, Liverpool, Leeds, London, Manchester, Newcastle, Nottingham and Sheffield on a primary urban area definition). However, note that in figure 5.3, the definition of major cities relies on Office for National Statistics rural-urban classification data for 'major' and 'minor' conurbations, which excludes Bristol.
Combined authority	Combined authorities are corporate bodies formed of two or more local government areas.
County council	Many areas in England have two tiers of local government: (1) county councils and (2) district, borough or city councils. County councils cover the whole county and are responsible for services which include transport, education and social care.
Crossrail	Crossrail, also known as the Elizabeth Line, is a new railway running for more than 60 miles from Reading and Heathrow in the west, underneath London and out to Shenfield and Abbey Wood in the east. Crossrail is expected to open at the end of 2018.
Crossrail 2	Crossrail 2 is a proposed new rail line which would run from the south-west to the north-east of London. Construction is expected to start in the early 2020s with the line opening in the early 2030s.
District council	Many areas in England have two tiers of local government: (1) county councils and (2) district, borough or city councils. District councils cover areas within county councils and are responsible for services which include housing and planning applications.
Dockless cycle	Dockless cycle is a service in which bikes can be located, hired and unlocked using a smartphone app and does not require a docking station.
Highways England	The publicly owned organisation which operates, maintains and improves England's 4,400 miles of motorways and major A roads.

Term	Meaning
HS2	High Speed 2 is a planned new high-speed rail network linking London, the West Midlands, Leeds and Manchester. The project is expected to be completed by 2033.
Integrated development plan	A single plan for urban development covering transport, housing and related infrastructure.
Interurban transport	Transport between cities.
Mayoral combined authority	Mayoral combined authorities are corporate bodies formed of two or more local government areas with an elected mayor. There are currently 7 mayoral combined authorities in the UK.
Metro mayor	A metro mayor is a person elected to chair a combined authority with powers to make decisions across the whole city region. There are currently 7 metro mayors in the UK.
Network Rail	Network Rail is the publicly owned organisation which owns and operates the railway infrastructure in England, Wales and Scotland.
Northern Powerhouse Rail	Northern Powerhouse Rail, also known as High Speed 3 (HS3) or Crossrail for the North, is a proposed strategic rail programme to connect the major cities in the North of England.
Transport for London (TfL)	Transport for London is the authority responsible for the transport system in London.
Unitary authority	In some parts of the country, one tier of local government provides all the local services, these are known as unitary authorities.
Urban transport	Transport within cities.

5. Reducing the risks of drought and flooding

Catchment Flood Management Plans	Catchment Flood Management Plans assess all types of inland flooding from rivers, groundwater, surface water and tidal flooding. Their purpose is to help the Environment Agency and their partners to plan and agree the most effective way to manage flood risk.
Common Agricultural Policy	The Common Agricultural Policy is a European Union system of subsidies and support programmes for agriculture.
Desalination	Desalination is the process of removing salt and other minerals from water.
Drainage and Wastewater Management Plans	Drainage and Wastewater Management Plans are long term plans for drainage and wastewater services. The framework for developing these plans is currently being defined by the 21st Century Drainage Programme.

Term	Meaning
Drought	<p>Drought is defined for this report as a period of such low rainfall that companies have to impose restrictions on households' water supply, by providing water only at certain times of the day or through temporary taps (standpipes) in the streets. The likelihood of a drought occurring is measured by its annual probability. Typically, the lower the chance of a drought occurring, the worse the drought is likely to be. The probabilities mentioned in this report are:</p> <p>1 per cent annual probability: approximately a 1 in 4 chance of drought by 2050; this is used as a proxy for the worst recorded drought in recent history</p> <p>0.5 per cent annual probability: approximately a 1 in 7 chance of drought by 2050</p> <p>0.2 per cent annual probability: approximately a 1 in 17 chance of drought by 2050.</p>
Grey / green infrastructure	Grey infrastructure refers to man-made, constructed assets such as pipes, sewers and dams. Green infrastructure makes use of natural processes to provide infrastructure services, such as wetlands, which can provide flood resilience and wider benefits such as enhancing biodiversity.
Managed retreat	Managed retreat is also known as coastal or defence realignment. It refers to the controlled flooding of a defined area to manage the risk of flooding or coastal erosion in the wider area.
Megalitre per day (Ml/day)	One Megalitre is equal to 1000 cubic metres or 1 million litres.
National water network	Coordinated and strategic transfers to move water between water companies and regions based on their needs.
Price Review	The process undertaken every five years by Ofwat to determine water company price controls for the next five years.
Shoreline Management Plans	Shoreline Management Plans identify the most sustainable approach to managing the flood and coastal erosion risks to the coastline looking up to 100 years ahead.
Surface water	Surface water is rain water that collects on the earth's surface. Surface water flooding occurs when intense rainfall overwhelms the capacity of local drainage systems.
Waste water	Water that has been affected by human use such as flushing and washing.
Water supply	The source, means and process of supplying water for people to use.
Water transfer	Water transfers involve water supply infrastructure to move water from one place to another. They can be made of man-made structures such as pipes and canals or a combination of such structures with rivers or other existing water courses.

Term	Meaning
6. Choosing and designing infrastructure	
Artificial intelligence	The development of machines that can perform tasks normally requiring human intelligence.
Digital twin	A digital model of infrastructure which will be able both to monitor infrastructure in real-time and to simulate the impacts of possible events such as a natural disaster or a new train line.
Hybrid bill	A hybrid bill is a set of proposals for introducing new laws, or changing existing ones. They are generally used to secure powers to construct and operate major infrastructure projects of national importance. Hybrid bills address both public and private matters.
Infrastructure and Projects Authority	The IPA is the government body responsible for supporting the delivery of infrastructure and other major projects, reporting to Cabinet Office and HM Treasury.
Infrastructure Client Group	The Infrastructure Client Group supports the development and exchange of best practice to improve the efficiency of the construction sector and help deliver major cost savings. It is made up of government and industry representatives from the major infrastructure clients.
National Policy Statements	National Policy Statements were established under the Planning Act 2008. They set out national policy for a sector in one place and are intended to provide greater clarity and certainty for the planning process to deliver Nationally Significant Infrastructure Projects.
Nationally Significant Infrastructure Projects	Nationally Significant Infrastructure Projects are large scale developments relating to energy, transport, water, or waste. They require only a single type of planning consent, known as a Development Consent Order, which is designed to be a much quicker process than applying for several individual planning consents separately. This was established under the Planning Act 2008 and amended by the Localism Act 2011.
Natural capital	Natural capital is the 'stock' of natural assets. These include: waters, land, air, species, minerals and oceans
Resilience	The United Nations defines resilience as the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner.
What Works Centre for Local Economic Growth	The What Works Centre for Local Economic Growth was set up in 2013 to analyse which policies are most effective in supporting and increasing local economic growth. It is an independent organisation funded by the Economic and Social Research Council and government.

Term	Meaning
7. Funding and financing	
Capital Gains Tax	Capital Gains Tax is a tax on the profit of the sale of an asset that has increased in value.
Capital markets	The part of the financial system involved in raising long term financing to support investment. It involves the issue and trading of equity (company shares), debt (corporate and government bonds), and other long term financial instruments.
Community Infrastructure Levy (CIL)	A fixed charge based on the development of new floor space. The money can be used to fund infrastructure that is needed as a result of development. It came into force in April 2010.
Economic infrastructure	Economic infrastructure refers to assets which facilitate economic activity such as: transport, energy, digital communications, water supply, waste management and flood risk management.
European Investment Bank (EIB)	The European Investment Bank is the European Union's bank for providing finance and expertise for sustainable investment projects that contribute to EU policy objectives.
Fuel duty	Fuel duty is a tax on petrol, diesel and other fuels used in vehicles or for heating.
Green Investment Bank (GIB)	The UK Green Investment Bank (now the Green Investment Group) was publicly owned, but is now an independent organisation owned by Macquarie Group Limited. The GIB was established in 2010 to increase the UK's ability to meet its environmental targets and commitments by getting green infrastructure projects financed more quickly than would otherwise have been the case.
Housing Infrastructure Fund	The Housing Infrastructure Fund is a government capital grant programme to help unlock new homes in areas with the greatest housing demand. The fund is £5 billion and funds the local infrastructure necessary before homes can be built.
Localism Act 2011	An Act of Parliament which amended powers for local authorities, including housing and planning.
Pooling restrictions	Limits on the number of number of Section 106 agreements which can be used to fund projects or types of infrastructure. According to Regulation 123 of the Community Infrastructure Levy regulations, they must be five or fewer.
Precept	A precept is an additional levy within Council Tax

Term	Meaning
Private finance Initiative (PFI)	The Private finance initiative is a method for the private sector to finance public infrastructure. In the UK, the original private finance initiative has been replaced by 'Private Finance 2'. The private partners invest equity, and take on significant levels of borrowing to finance the upfront costs of infrastructure projects. The project is then leased back to the relevant government body which makes regular payments to the project company, typically over 25 years. More generically, the term 'public private partnership' is used to cover a range of cooperative arrangements between public and private sector bodies, including private finance initiative type arrangements.
Risk-adjusted interest rates	The risk-adjusted interest rate refers to the rate of interest on debt financing that is adjusted to reflect project specific risks, adding a premium to the cost of debt financing.
Section 106 agreements	Legal agreements between local authorities and developers to mitigate the impact of new developments through contributions towards site-specific infrastructure, including affordable housing. They arise from section 106 of the Town and Country Planning Act 1990.
Spending Review 2019	Spending Reviews set out the government's spending plans. The next Spending Review will take place in 2019.
Stamp Duty	Stamp Duty is a tax paid when purchasing a property. It is calculated based on the purchase price of the property.
Whole life cost	The whole life cost is the amount that a product or service costs over its lifetime. It includes the initial capital cost, the costs to run, maintain, repair and upgrade, as well as the eventual disposal costs.

Annex B: Acknowledgements

The Commission is grateful to everyone who has engaged with the National Infrastructure Assessment process. The list below sets out organisations that have engaged with the Commission since publication of its interim report *Congestion, Capacity, Carbon: Priorities for National Infrastructure* through at least one of the following means:

- submitting consultation responses to the interim report
- participating in roundtables
- attending meetings with members of the Commission Secretariat.

Former Commissioners Lord Adonis, Demis Hassabis, Lord Heseltine and Sir Paul Ruddock were all members of the Commission at earlier stages of the Assessment process and contributed to it throughout their tenure.

The Commission would like to thank everyone who responded to earlier consultations (on the Process and Methodology for the Assessment, and the Call for Evidence on the Assessment), commented on the driver papers, and participated in initial workshops and roundtables. The Commission acknowledges the contribution of its expert advisory groups for their input throughout the Assessment process, the Infrastructure Transitions Research Consortium for support with modelling, and the consultants that have been engaged by the Commission and contributed to developing its evidence base.

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Organisations engaged

360 Environmental
 ABB Group
 Adaptation Sub-Committee of the Committee on Climate Change
 Adelard LLP
 AECOM
 Affinity Water
 Air Broadband
 Airport Operators Association
 Alan Turing Institute
 Allerdale Borough Council
 Allen & Overy
 Amey
 Anaerobic Digestion and Bioresources Association
 Anglian Central Regional Flood & Coastal Committee
 Anglian Water
 Anthesis Group
 Arqiva
 Arriva
 Ascential
 Asian Infrastructure Investment Bank
 Association for Consultancy and Engineering
 Association for Decentralised Energy
 Association for Project Management
 Association for the Conservation of Energy
 Association of British Insurers
 Association of Directors of Environment, Economy, Planning and Transport
 Atkins
 Atlantic Gateway
 Atlantic SuperConnection LLP
 Aurora Energy Research
 Aviva
 BAI Communications
 Bath and North East Somerset Council
 Biffa
 Biofuelwatch
 Birmingham City Council
 Bit Commons
 Blueprint for Water
 Borough of Poole
 Bournemouth Borough Council
 BPP Consulting
 Bright Blue
 Bristol City Council
 British Broadcasting Corporation
 British Ceramic Confederation
 British Chambers of Commerce
 British Glass
 British Motorcyclists Federation (Enterprises) Limited
 British Plastics Federation
 British Ports Association
 British Property Federation
 British Retail Consortium
 British Standards Institute
 British Telecom
 Broadband for the Rural North Ltd
 Broadband Stakeholder Group
 Brownsholme Hall
 Buckinghamshire Thames Valley Local Enterprise Partnership
 Building Research Establishment
 Business in the Community
 Cabinet Office
 Cadent Gas
 Cambridge Centre for Smart Infrastructure and Construction
 Cambridge Econometrics
 Campaign for Better Transport
 Campaign to Protect Rural England
 Campbell Lutyens

Carbon Capture and Storage Association
Carbon Connect
Carbon Trust
Cardiff Council
Central Bedfordshire Council
Centre for Cities
Centre for Progressive Policy
Centre for Transport Studies, Imperial College London
Centre for Urban and Regional Development Studies, Newcastle University
Chargemaster
Chartered Institute of Highways and Transportation
Chartered Institute of Housing
Chartered Institute of Transport and Logistics
Chartered Institution of Building Services Engineers
Chartered Institution of Civil Engineering Surveyors
Chartered Institution of Wastes Management
Chartered Institution of Water and Environmental Management
Chatham House
Cheshire and Warrington Local Enterprise Partnership
Cheung Kong Hutchison Holdings
Cisco
City and Financial Global
City of Bradford Metropolitan District Council
CityFibre
Clarion Housing Group
Climate Genocide Act Now
Coca-Cola
Commission on Travel Demand
Committee on Climate Change
Committee on Fuel Poverty
Common Futures Network
Community Futures
Community R4C
Compulsory Purchase Association
Confederation of British Industry
Confederation of Paper Industries
Confederation of Passenger Transport UK
Connect Plus
Constructing Excellence in Wales
Construction Industry Research and Information Association
Consumer Council for Water
Core Cities
Cornwall and Isles of Scilly Local Enterprise Partnership
Cornwall Council
Cory Riverside Energy
Country Land & Business Association
Crossrail 2
Cumbria County Council
David Lock Associates
db symmetry
Deloitte
Design Commission for Wales
Design Council
Digital Lancashire
Dorset Local Enterprise Partnership
Drax Group plc
Drinking Water Inspectorate
E.ON UK plc
E3G
East Northants District Council
Eden Council
EDF Energy
EE Limited
EEF Limited
Electric Infrastructure Security Council
Electricity North West
Element Energy

ELEXON
Ellen MacArthur Foundation
Ely Group of Internal Drainage Boards
ENCORE+
Energy & Utilities Alliance
Energy Agency
Energy Insight Limited
Energy Networks Association Limited
Energy Systems Catapult
Energy Technologies Institute
Energy UK
EngineeringUK
Environment Agency
Environmental Change Institute
University of Oxford
Environmental Services Association
Essex and Suffolk Water
Essex County Council
Eunomia
European Bank for Reconstruction and Development
European Commission
European Investment Bank
European PPP Expertise Centre
Existing Homes Alliance Scotland
FCC Environment
Federation of Master Builders
FirstGroup plc
Fitch Ratings
Flood Hazard Research Centre
Middlesex University
Flood Re
Flood Limited
Food and Drink Federation
Ford
Francis Taylor Building
Freight on Rail
Freight Transport Association
Freightliner Group Limited
Friends of the Earth England, Wales and Northern Ireland
Frontier Economics
FTTH Council
Funding Group for River Thames Flood Alleviation Scheme
Future Cities Catapult
GB Railfreight Limited
Geovation
Gigaclear
Global Change Institute
Global Infrastructure Hub
Global Infrastructure Investor Association
Gloucestershire County Council
Go-Ahead
Greater London Authority
Greater Manchester Combined Authority
Green Alliance
Green Investment Group
Greenpeace
Greenwood Consultants
Hafren Power Limited
Halcyon Tidal Power LLC
Hampshire & Isle of Wight Wildlife Trust
Hampshire County Council
Hastoe Housing Association and Sustainable Homes Limited
Health and Safety Executive
Heart of the South West Local Enterprise Partnership
High Speed Rail Industry Leaders
Highways England
Historic England
Home Builders Federation
Homes England
Horizon Nuclear Power
HR Wallingford
HS2 Limited

Hull City Council	Lancaster & District Chamber of Commerce
Hutchison 3G UK Limited	Lancaster City Council
Hyperoptic	Lancaster University
ifibre	Legal & General
Imperial College London	Leicester City Council
INCPEN	Lincolnshire County Council
Independent Networks Cooperative Association	Liverpool City Region Combined Authority
Infrastructure Ontario	Living PlanIT
Infrastructure Operators Adaptation Forum	Lloyds Register Foundation
Infrastructure Transitions Research Consortium	Local Authority Recycling Advisory Committee
InLinkUK	Local Government Association
Innovate UK	Local Government Association Coastal Special Interests Group
INRIX	Local Government Flood Forum
Institute for Fiscal Studies	Local Government Technical Advisers Group
Institute for Government	London and Quadrant Housing Trust
Institute for Public Policy Research	London Councils
Institute for Transport Studies	London School of Economics and Political Science
Institute of Asset Management	Long Term Infrastructure Investors Association
Institution of Engineering and Technology	Longbay Seapower Limited
Institution of Civil Engineers	Low Carbon Contracts Company
Integrated Transport Planning	Luton Borough Council
International Monetary Fund	M&G Investments
Ipsos MORI	Mace
ITS Technology Group	Macquarie Group
Jacobs Engineering Group Inc.	Manchester Airports Group
Jaguar Land Rover	Markides Associates
JBA Consulting	Marks and Spencer
Kent County Council	Mayor of Cambridgeshire and Peterborough
Kettering Borough Council	Mayor of Greater Manchester
Kilbride Rail	Mayor of Liverpool City Region
Kingspan Insulation Limited	Mayor of London
KPMG	Mayor of the Tees Valley
Laing O'Rourke	
Lancashire Care NHS Foundation Trust	
Lancashire County Council	

Mayor of the West Midlands
Mayor of the West of England
Merseytravel
Met Office
Metronet UK (now M24Seven)
Middlesex University
Midlands Connect
Milton Keynes Council
Mineral Products Association
Mineral Wool Insulation Manufacturers Association
Ministry for the Economy and Finances (France)
Ministry of Transport & Communications (Norway)
Mitsubishi UFJ Financial Group
Mobile UK
Motorcycle Industry Association
Mott MacDonald
MWH Global
National Association of Waste Disposal Officers
National Audit Office
National Energy Action
National Farmers Union
National Flood Forum
National Grid
National Infrastructure Planning Association
National League of Cities
National Nuclear Laboratory
Natural Capital Committee
Natural Energy Wyre
Natural England
NERA Economic Consulting
Nesta
Network Rail
New Civil Engineer
Newcastle City Council
Newcastle University
Nexus
Nissan
North East Combined Authority
North West Business Leadership Team
Northamptonshire County Council
Northern Gas Networks
Northern Ireland Executive
Northern Ireland Fuel Poverty Coalition
Northumberland County Council
Northumbrian Water
Norton Rose Fulbright
Nottingham City Council
Nuclear Industry Association
O2
Ofcom
Office of Road and Rail
Ofgem
Ofwat
Old Oak and Park Royal Development Corporation
OMEGA Centre
Openreach
Orbit Group Limited
Ordnance Survey
Organisation for Economic Co-operation and Development
Ørsted
Packaging Federation
Peabody
Peel Energy
Peel Land and Property
Pegasus Group
Pennon Group
Pensions Infrastructure Platform
Pinsent Masons
Pipe Jacking Association
Plymouth City Council
Policy Connect
Policy Exchange

Pöyry
Prism Consulting Group LLC
Proctor and Gamble
Prospective
RAC Foundation
RAC
Radioactive Waste Management
Rail Delivery Group
Rail Freight Group
Railway Industry Association
Recycling Technologies
Regulatory Economics
Renewable Energy Association
Resource and Waste Solutions
Partnership
Resource Futures
Resources and Waste UK
Ricardo
Risk Management Solutions
Road Haulage Association Limited
Rod Rainey & Associates Limited
Rolls Royce
Royal Academy of Engineering
Royal Institution of British Architects
Royal Institution of Chartered Surveyors
Royal Society
Royal Society for the Protection of Birds
Royal Town Planning Institute
RWE Generation UK
SAID Business School
Savills plc
Sayers and Partners
Scottish and Southern Energy Enterprise
Scottish Association for Public Transport
Scottish Carbon Capture & Storage
Scottish Environment Protection Agency
Scottish Federation of Housing
Associations
Scottish Futures Trust
Scottish Government
Scottish Power
Severn Trent Water
SGN
Sheffield City Region
Shropshire Council
Siemens
Skanska
Sky
Smarter Cambridge Transport
Society of Motor Manufacturers and
Traders
South East England Councils
South East Essex Action Group Alliance
South East Water
South Gloucestershire Council
South West Water
South Yorkshire Passenger Transport
Executive
Southern Water
SSE
Stagecoach
Steer Davies Gleave
SUEZ UK
Surrey County Council
Sustainable Energy Association
Sustrans
Sweco
Swindon Borough Council
Tactis
TalkTalk
Tantalum Corporation
Tarmac
Taylor Wimpey
Tech UK
Technical University Bergakademie
Freiberg
Tees Valley Combined Authority
Teesside Collective
Tesco

Thames Water	University of Glasgow
The Infrastructure Forum	University of Hull
The Law Society of England and Wales	University of Leeds
The Society for Poole	University of Manchester
Three	University of Northampton
Tidal Lagoon	University of Oxford
Tolvik Consulting	University of Sheffield
Town and Country Planning Association	University of Sussex Science Policy Research Unit
Trades Union Congress	Urban Transport Group
Transition Town Brixton	Urban Water Cycle Solutions
Transport for Greater Manchester	Urbed
Transport for London	Urenco
Transport for the North	Valpak
Transport for West Midlands	Vattenfall
Transport Research Laboratory	Veolia
Transport Systems Catapult	Virgin Media
TravelWatch NorthWest	Viridor
Trees and Design Action Group	Vivid Economics
Turner & Townsend	Vodafone
UCL Institute for Innovation and Public Purpose	Waste and Resources Action Programme
UK Broadband Limited	Water Resources East
UK Collaboratorium for Research on Infrastructure and Cities	Water Resources in the South East
UK Energy Research Centre	Water UK
UK Green Building Council	Waterscan
UK Power Networks	Waterwise
UK Rainwater Management Association	Welsh Government
UK Regulators Network	West of England Combined Authority
UK Water Industry Research	West Yorkshire Combined Authority
Unilever	Westinghouse Electric Company LLC
Uniper SE	Westminster Energy Environment & Transport Forum
United Kingdom Onshore Oil and Gas	Westminster Energy Forum
United Kingdom Without Incineration Network	Wheels for Wellbeing
United Utilities	Wildfowl & Wetlands Trust
University College London	Wildlife and Countryside Link
University of Cambridge	Wiltshire Council
University of Edinburgh	Wood Plc
University of Exeter Energy Policy Group	Woodland Trust

WSP Global

WWF

Yorkshire Water

Zero Carbon Futures

ZTE Corporation

Annex C: Supplementary documents

The Commission has produced or commissioned the reports listed below as part of the analysis supporting the National Infrastructure Assessment. All reports are available on the Commission's website or will be when published.

National Infrastructure Commission reports

National Infrastructure Assessment impact and costings notes, July 2018

Technical annex: Analysis of drought resilience, July 2018

Technical annex: Flood modelling, July 2018

Technical annex: Energy and fuel bills today and in 2050, July 2018

Technical annex: Tidal power, July 2018

Technical annex: Power system effects of electric vehicles, July 2018

Technical annex: Proposed analytical framework for evaluating the performance of private financing and traditional procurement, July 2018

Preparing for a drier future: England's water infrastructure needs, April 2018

Congestion, Capacity, Carbon – Priorities for National Infrastructure, October 2017

 Congestion, Capacity, Carbon – Modelling annex, October 2017

 Congestion, Capacity, Carbon – Modelling annex data, October 2017

The impact of the environment and climate change on future infrastructure supply and demand, June 2017

Economic growth and demand for infrastructure services, March 2017

The impact of population change and demography on future infrastructure demand, December 2016

The impact of technological change on future infrastructure supply and demand, December 2016

National Infrastructure Assessment: Call for evidence, October 2016

The National Infrastructure Assessment process and methodology: Consultation response, October 2016

Annex: Responses to National Infrastructure Assessment process and methodology consultation overview, October 2016

National Infrastructure Assessment process and methodology: a consultation, May 2016

Reports commissioned for the Assessment

Institute for Fiscal Studies (forthcoming), Property Value Uplift Tool

Arup (July 2018), Congestion, Capacity, Carbon: priorities for national infrastructure, report on consultation responses

Ipsos MORI (July 2018), National Infrastructure Commission phase 2: public research

Anthesis Consulting (July 2018), Waste infrastructure analysis for England

Atkins (July 2018), Analysis of the costs of emergency response options during a drought

Aurora Energy Research (July 2018), Power sector modelling: system cost impact of renewables

Energy Systems Catapult (July 2018), Electric vehicle charging cost analysis

Eunomia (July 2018), Comparative study of national infrastructure financing institutions

Gibbons and Graham (July 2018), National Infrastructure Commission urban capacity economic analysis.

JBA Consulting (July 2018), Flood standards of protection and risk management activities

Lomax and Smith (July 2018), Effect of capacity constraints on population and employment distribution

Prospective (July 2018), Transport connectivity

Publica (July 2018), Design Task Force, Design and Infrastructure – Sector review of attitudes

Publica (July 2018), Design Task Force, Developing design principles for national infrastructure

Regulatory Economics (July 2018), Analysis of the costs of water resource management options to enhance drought resilience

Steer Davies Gleave (July 2018), Urban transport network review

Expedition Engineering and Marko&Placemakers (July 2018), Design Task Force, The value of design in infrastructure delivery

Vivid Economics (July 2018), The role and impact of the EIB and GIB on UK infrastructure investment

Element Energy (May 2018), Cost analysis of future heat infrastructure options

Arup and University College London (December 2017), Infrastructure and digital systems resilience, literature review

Arup and University College London (December 2017), Infrastructure and digital systems resilience

Frontier Economics (December 2017), Future benefits of broadband networks

Tactis and Prism Business Consulting (December 2017), Costs for digital communications infrastructures

Simpson and Ives (November 2017), Scenarios of future water availability in the UK

BritainThinks (October 2017), National Infrastructure Commission report from citizen research

Arup (October 2017), International infrastructure governance report

Cambridge Economic Policy Associates (October 2017), Financing for infrastructure summary report

Cambridge Economic Policy Associates (October 2017), Review of the UK infrastructure financing market

Cambridge Economic Policy Associates (October 2017), UK infrastructure pipeline analysis

JBA Consulting, SDG Economic Development, Temple and GreySky (October 2017), National Infrastructure Commission, performance measures

International Transport Forum (March 2017), Strategic infrastructure planning; international best practice

Annex D: Recommendations

1. Building a digital society

The Commission recommends that government should set out a nationwide full fibre connectivity plan by spring 2019, including proposals for connecting rural and remote communities. This should ensure that full fibre connectivity is available to 15 million homes and businesses by 2025, 25 million by 2030 with full coverage by 2033. To achieve these targets:

- Ofcom should promote network competition to drive the commercial rollout of full fibre, by deregulating where competition is effective and guaranteeing a fair bet on risky investments before regulating any uncompetitive areas.
- Government should part subsidise rollout to rural and remote communities, beginning by 2020, starting with the hardest to reach areas and community self-build.
- Government and Ofcom should allow for copper switch-off by 2025.
- Government and Ofcom should take action to cut the cost of full fibre deployment including:
 - Government should ensure the processes for obtaining wayleaves and connecting new builds are the same for digital infrastructure as other utilities by 2019.
 - Local government should designate ‘digital champions’ to improve telecoms processes such as street work permissions and access to publicly owned assets.
 - Ofcom should monitor the accessibility of Openreach’s duct and pole infrastructure by levels of usage.

2. Low cost, low carbon

The Commission recommends that government should set out a pipeline of pot 1 Contracts for Difference auctions, to deliver at least 50 per cent renewable generation by 2030, as part of the transition to a highly renewable generation mix. Government should:

- Move technologies that have recently become cost competitive, such as offshore wind, to pot 1 following the next Contracts for Difference auction in Spring 2019. Pot 1 should be used for the overwhelming majority of the increase in renewable capacity required.

- Publish indicative auction dates and budgets for the next decade by 2020.
- Over time take whole systems costs into account in Contracts for Difference auctions, as far as possible.
- Consider whether there is a case for a small-scale, pot 2 auction in the 2020s, if there are technologies which are serious contenders for future pot 1 auctions.
- Not agree support for more than one nuclear power station beyond Hinkley Point C, before 2025.

The Commission recommends that government needs to make progress towards zero carbon heat:

- Establishing the safety case for using hydrogen as a replacement for natural gas, followed by trialling hydrogen at community scale by 2021.
- Subject to the success of community trials, launching a trial to supply hydrogen to at least 10,000 homes by 2023, including hydrogen production with carbon capture and storage.
- By 2021, government should establish an up to date evidence base on the performance of heat pumps within the UK building stock and the scope for future reductions in the cost of installation.
- Set a target for the rate of installations of energy efficiency measures in the building stock of 21,000 measures a week by 2020, maintained at this level until a decision on future heat infrastructure is taken. Policies to deliver this should include:
 - Allocating £3.8 billion between now and 2030 to deliver energy efficiency improvements in social housing.
 - Government continuing to trial innovative approaches for driving energy efficiency within the owner occupier market.
 - Government setting out, by the end of 2018, how regulations in the private rented sector will be tightened and enforced over time.

The Commission recommends that government should set a target for recycling 65 per cent of municipal waste and 75 per cent of plastic packaging by 2030. Government should set individual targets for all local authorities and provide financial support for transitional costs. The government should establish:

- Separate food waste collection for households and businesses (to enable production of biogas) by 2025.
- Clear two symbol labelling (recyclable or not recyclable) across the UK by 2022.
- A consistent national standard of recycling for households and businesses by 2025.

- Restrictions on the use of hard-to-recycle plastic packaging (PVC and polystyrene) by 2025.
- Incentives to reduce packaging and for product design that is more easily recyclable by 2022.
- A common data reporting framework for businesses handling commercial and industrial waste by the end of 2019, ideally through voluntary reporting but if necessary by legislation.

3. Revolutionising road transport

The Commission recommends that government, Ofgem and local authorities should enable the roll out of charging infrastructure sufficient to allow consumer demand to reach close to 100 per cent electric new car and van sales by 2030. Government should address the implications of technological innovation in long term transport planning processes, including the next rail control period and road investment strategy.

- Ofgem should take on the role of regulating the interaction between electric vehicle charge points and the electricity network immediately, ensuring that electric vehicle charging and vehicle to grid services contribute to the optimisation of the energy system. Government, industry and Ofgem should work together to set minimum standards for a network of interoperable, smart charge points.
- Ofgem should commission electricity network operators to work with charge point providers to identify potential anticipatory investments required to accommodate public charging infrastructure. Opportunities for investment within the current price control period should be identified by Summer 2019.
- Government should place a requirement on local authorities to work with charge point providers to allocate 5 per cent of their parking spaces (including on-street) by 2020 and 20 per cent by 2025 which may be converted to electric vehicle charge points.
- Government should subsidise, by 2022, the provision of rapid charge points in rural and remote areas, where the market will not deliver in the short term.
- Government should establish a centre for advanced transport technology in the Department for Transport to bring together work on technological innovation and ensure its implications are central to future investment proposals. This should include developing and overseeing the Commission's proposed connected and autonomous vehicles framework.

4. Transport and housing for thriving city regions

The Commission recommends that government should make £500 million a year of funding available from 2025/26 to 2034/35 for local highways authorities to address the local road maintenance backlog.

The Commission recommends that cities should have the powers and funding they need to pursue ambitious, integrated strategies for transport, employment and housing.

- By 2021, metro mayors and city leaders should develop and implement long term integrated strategies for transport, employment and housing that will support growth in their cities.
- By 2021, government should ensure city leaders have the right powers to deliver these integrated strategies, including the power for metro mayors to make decisions on major housing development sites.
- Government should set out devolved infrastructure budgets for individual cities for locally determined urban transport priorities in line with the funding profile set out by the Commission. Budgets for 2021-2026 should be confirmed by mid 2019. Government should pass legislation, by 2020, requiring cities to be given regular five year infrastructure budgets.
- Government should allocate significant long term funding for major capacity upgrades in selected growth priority cities, in line with the funding profile set out by the Commission. Cities benefiting from major projects should make commitments on housing delivery and provide at least 25 per cent of funding. Priority cities should be identified by mid 2019, with long term investment commitments agreed by 2020. Future rounds should take place no more than twice a parliament.

5. Reducing the risks of drought and flooding

The Commission recommends that government should set out a strategy to deliver a nationwide standard of resilience to flooding with an annual likelihood of 0.5 per cent by 2050 where this is feasible. A higher standard of 0.1 per cent should be provided for densely populated areas where the costs per household are lower. To deliver the strategy:

- By the end of 2019, government should put in place a rolling 6 year funding programme in line with the funding profile set out by the Commission. This should enable efficient planning and delivery of projects and address the risks from all sources of flooding.
- The Environment Agency should update plans for all catchments and coastal cells in England before the end of 2023. These should identify how risk can be managed most effectively using a combination of measures

including green and grey infrastructure, spatial planning and property level measures.

- Water companies and local authorities should work together to publish joint plans to manage surface water flood risk by 2022.
- The Ministry of Housing, Communities and Local Government and planning authorities should ensure that from 2019 all new development is resilient to flooding with an annual likelihood of 0.5 per cent for its lifetime and does not increase risk elsewhere.

The Commission recommends that government should ensure that plans are in place to deliver additional supply and demand reduction of at least 4,000 MI/day. Action to deliver this twin-track approach should start immediately:

- Ofwat should launch a competitive process by the end of 2019, complementing the Price Review, so that at least 1,300 MI/day is provided through (i) a national water network and (ii) additional supply infrastructure by the 2030s.
- The Department for Environment, Food and Rural Affairs should set an objective for the water industry to halve leakage by 2050, with Ofwat agreeing 5 year commitments for each company (as part of the regulatory cycle) and reporting on progress.
- The Department for Environment, Food and Rural Affairs should enable companies to implement compulsory metering by the 2030s beyond water stressed areas, by amending regulations before the end of 2019 and requiring all companies to consider systematic roll out of smart meters as a first step in a concerted campaign to improve water efficiency.

6. Choosing and designing infrastructure

The Commission recommends that government should publish good quality data on infrastructure costs and performance. All public bodies taking decisions on strategic economic infrastructure should publish the forecast costs and benefits of their major infrastructure projects at each appraisal stage and at a suitable point after completion, by the end of 2019. The Infrastructure and Projects Authority should work with departments to ensure that costs are comparable between sectors.

The Commission recommends that design should be embedded into the culture of infrastructure planning, to save money, reduce risk, add value, support environmental net gain and create a legacy that looks good and works well, by:

- Government ensuring that all Nationally Significant Infrastructure Projects, including those authorised through hybrid parliamentary bills, have a board level design champion and use a design panel to maximise the value provided by the infrastructure.

- Design panels for nationally significant infrastructure projects having regard to design principles to be published by the National Infrastructure Commission based on advice received from the national infrastructure design group.

7. Funding and financing

The Commission recommends that government should deliver long term certainty over infrastructure funding by adopting the funding profile set out in the ‘fiscal remit’ table in Spending Review 2019 and other future spending plans.

The Commission recommends that government should maintain access to the European Investment Bank if possible. If access is lost, a new, operationally independent, UK infrastructure finance institution should be established by 2021. To enable this, government should consult on a proposed design of the new institution by Spring 2019. The consultation should cover:

- Functions, including provision of finance to economic infrastructure projects in cases of market and coordination failures; catalysing innovation; and acting as a centre of excellence on infrastructure project development, procurement and delivery.
- A clear mandate, including sound banking, additionality and having a wider economic and social impact.
- Governance to safeguard the operational independence of the institution.

The Commission recommends that local authorities should be given further powers to capture a fair proportion of increases in the value of land from planning and infrastructure provision. To enable this, government should:

- Remove pooling restrictions on Section 106 in all circumstances, through forthcoming secondary legislation by 2020.
- Remove the ballot requirement for upper tier authorities’ powers to levy a business rate supplement of 2p or less in the pound for infrastructure, except where the supplement exceeds one third of scheme costs by 2021.
- Give local authorities powers to levy zonal precepts on council tax, where public investments in infrastructure drive up surrounding property values by 2021.
- Provide greater certainty in compulsory purchase compensation negotiations by including independent valuations early in the process to be paid for by the acquiring authority by 2021.



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