The Second National Infrastructure Assessment

Impact and Costings for Recommendations

October 2023

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Introduction and Summary

The Commission is committed to transparency around the costs and impacts of its recommendations, as reflected in the remit letter from the Chancellor.[1] This document includes the Commission's assessment of the impact and costs of recommendations made within the second National Infrastructure Assessment affecting the energy, transport, digital and waste sectors. They consider how the recommendations could have significant implications on spending, bills and the wider UK economy, carbon emissions and the environment.

Each sector's section presents:

- the impact of the recommendations on the Commission's objectives to support sustainable economic growth across all regions of the UK, improve competitiveness, improve quality of life and support climate resilience and the transition to net zero
- the estimated costs of the recommendations and their impact on the Commission's fiscal and economic remits
- distributional costs and impacts of recommendations on protected groups
- uncertainty around estimates and the balance of evidence behind recommendations.

The Commission's objectives

This document sets out how the recommendations in the Assessment contribute towards the Commission's four objectives. A previous series of discussion papers set out the Commission's approach to how infrastructure contributes to each of these objectives.

Growth Across Regions[2] interprets the objective of growth across all regions in the UK as supporting faster growth in low productivity regions and balancing this with maintaining the economic performance of high productivity regions.

Improving Competitiveness[3] identifies three ways infrastructure can contribute to competitiveness: improving access to markets, improving access to mobile labour and capital, and being a source of globally significant clusters and assets.

Natural Capital and Environmental Net Gain[4] sets out the outcomes by which natural capital principles can achieve environmental net gain when developing infrastructure projects. The Commission is also required to consider potential interactions between recommendations and the government's legal target to halt biodiversity loss by 2030 and implementing biodiversity net gain. This document assesses the environmental impacts of the Commission's recommendations against areas covered in the government's 25 year environment plan in each **Section 5.**

In 2021 the government added a fourth objective to the Commission's remit, to support climate resilience and the transition to net zero carbon emissions by 2050, the government's legal target.

Quality of Life[5] sets out six domains by which the Commission assesses the impact of infrastructure on overall wellbeing. The domains and their definitions are set out in **Table 1**, which are applied in each **Section 2.**

[1] HM Treasury (2021), Remit Letter to the National Infrastructure Commission
[2] National Infrastructure Commission (2020), Growth across regions
[3] National Infrastructure Commission (2020), Improving Competitiveness
[4] National Infrastructure Commission (2021), Natural capital and environmental net gain
[5] National Infrastructure Commission (2022), Quality of life

Table 1: The Commission's quality of life domains

Domain name	Definition
Health	The impact of infrastructure services on physical and mental health
Local and natural surroundings	The impact of infrastructure design and operation on the local and natural environment
Connections	The physical connections (transport networks) and digital connections (fixed and mobile broadband) that link people, communities and businesses
Affordability	The distributional impact of the cost of infrastructure services that domestic consumers pay through bills or fares and the overall cost of infrastructure over time
Comfort and convenience	Users' experience with infrastructure services including the level of satisfaction derived from these services
Employment	How infrastructure acts as an enabler for patterns of economic activity and therefore access to jobs

The Commission's remit

To satisfy its obligations to the fiscal and economic remits, the Commission has assessed the direct impact of these recommendations on public capital expenditure (fiscal remit) and other sources of infrastructure funding including consumer bills (economic remit).

Distributional impacts

The Commission's analysis[6] demonstrates that in aggregate, the recommendations in the Assessment should not have a disproportionate impact on households with lower incomes. Households on the highest incomes spend most on infrastructure, so would stand to save more money from falling bills than those on low incomes. But as a proportion of total household expenditure, it is low income households that will likely benefit most. The Commission has recommended supporting lower income households where recommendations would otherwise have a disproportionate impact on them — for example covering the full cost of heat pumps for these households. The key distributional impacts of the Commission's recommendations are:

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

Accounting for uncertainty

This document tests how recommendations made in the Assessment fare in different possible future states of the world based on a set of drivers, and to changes in assumptions. The Commission's uncertainty framework[7] sets out three risk classifications to consider when

[6] National Infrastructure Commission (2023), Distribution analysis technical annex
[7] National Infrastructure Commission (2022), Managing uncertainty in the second National Infrastructure Assessment

managing a portfolio of infrastructure projects or policies when the probabilities of different future events or states of the world are unknown, laid out in **Table 2**.

Table 2: The Commission's uncertainty classifications

Classification	Detail
Robust investment	Investments that perform acceptably well across a wide range of future scenarios
Strategic bet	Investments that perform well in a small number of scenarios and so may not pay off, but when they do the payoff is very significant
Hedge	Investments that pay off in scenarios where other investment, projects or policies would perform poorly

The Commission has also identified a series of investments that will only be necessary in some future scenarios. These investments are part of the 'uncertainty and adaptive pathways' spend line in the fiscal remit. These are fully costed and affordable but should not be committed to until more is known about whether they are required. This includes investments if the world warms more than expected, if decarbonising the economy requires more intervention than planned, or if committed infrastructure projects overspend. This uncertainty and adaptive spending complements the core spending recommendations within the fiscal remit, ensuring overall public investment via the fiscal budget is robust to uncertainty.

Each sector's impact and costing note sees the Commission review these factors in a standard format for the energy, transport, digital and waste sectors. Numbers presented here are rounded to nearest 100 million or 10 million for figures below 100 million. Each is broken down into seven sections:

Section 1: Assessment recommendations and outcomes
Section 2: Contribution towards the Commission's objectives
Section 3: Impact on the Commission's fiscal remit
Section 4: Impact on the Commission's economic remit
Section 5: Environmental impacts
Section 6: Distributional impacts
Section 7: Uncertainty

Energy Impact and Costings

Section 1: Assessment recommendations and outcomes

The Commission has made 14 energy recommendations within the Assessment.[8]

The Assessment sets out recommendations on economic infrastructure in the energy sector, which is defined as how electricity is generated, how energy is transported and stored, how buildings are heated and how new low carbon energy sources can support the economy to decarbonise. To tackle climate change and ensure energy security, there should be a move away from a reliance on fossil fuels and towards the use of electricity to power homes, vehicles and industry.

Outcomes

The main outcomes of the Commission's energy recommendations are to deliver a decarbonised energy system that meets net zero by 2050, as well as interim carbon budgets. Recommendations will deliver a reduction in the use of unabated gas to generate electricity and heat buildings. In addition, recommendations ensure hydrogen and carbon capture and storage networks develop to support decarbonisation across the economy.

Electricity demand is set to increase by around 50 per cent by 2035 as surface transport and heating are electrified and industry is increasingly powered by electricity. The electricity system will need to run mostly from renewable power sources like wind and solar. An energy system predominantly running on electricity, rather than fossil fuels, is more efficient, cleaner and better insulated from volatile fuel prices. This should roughly halve the average household cost for energy compared to today's high levels.

The Commission's energy recommendations are underpinned by scenario analysis by Aurora Energy Research[9] and Arup[10] supplemented by Commission assumptions and judgements in further modelling.

Level of investment

Significant investment is needed to deliver a decarbonised energy system, from both the private and public sector. Policy decisions by government need to leverage increased near term investment by the private sector.

The Commission recommends that government investment in the energy system is focused on heat decarbonisation. Enhanced support for all, with additional support for households on lower incomes, will enable the transition to be affordable and fair. This public expenditure sits within the Commission's fiscal remit.

To achieve the above outcomes over the next 30 years, the estimated average level of investment in the energy system from 2025 is around £40 billion per year, in 2022 price terms, reaching peak annual investment of £55 billion in the mid 2030s. The profile of investment ramps up through the 2030s and peaks to achieve the Sixth Carbon Budget. Two thirds of this will need to come from the private sector. Presented as a per year average between 2025 and 2050, this breaks down as:

- £20 to £35 billion for the energy industry to invest in energy infrastructure[11]

[8] National Infrastructure Commission (2023), second National Infrastructure Assessment
[9] Aurora Energy Research (2023), Energy sector modelling to support the second National Infrastructure Assessment
[10] Arup (2023), Future of Great Britain's Gas Networks
[11] This includes new hydrogen generation assets, hydrogen and carbon transmission pipes and storage, capital to set up and maintain a strategic reserve, ongoing capital investment in generation capacity, and gas and electricity transmission and distribution network.

- £3 to £9.5 billion from households investing in heating and energy efficiency, and another £350 to £750 million from businesses investing in heating and energy efficiency
- £0.5 to £2.5 billion to decarbonise public sector buildings by deploying heat pumps, heat networks and energy efficiency
- £3 to £12 billion for a package of government subsidies for households and small businesses to purchase a heat pump or connect to a heat network. This is frontloaded in spend through the 2030s. See **Section 3** for a more detailed breakdown.

Contributing to the capital cost of household heating, via the proposed package of subsidy support, is an important role for government, but it is also a temporary one. Once households have transitioned to heat pumps or heat networks, this spending will no longer be required.

Funding and financing

Energy infrastructure — supply, transmission and distribution — is built and operated by the private sector and paid for through energy bills. Businesses can also pass their costs of financing onto users. Therefore the costs of economic infrastructure services are ultimately paid for by households. **Section 4** discusses the magnitude of impact of the Commission's energy recommendations on households, businesses and government as part of its economic remit. **Section 6** considers how the distribution of costs across households has been accounted for.

Capital spending in the energy system by the public sector is smaller by comparison, focused on its own building stock and some support mechanisms to bring forward low carbon technologies, such as support for the installation of heat pumps. New costs to the public sector include a recommended package of subsidies to support decarbonisation of private buildings. These costs come under the Commission's fiscal remit, outlined in **Section 3**. Government is responsible for financing this expenditure through taxation and borrowing and must balance this amongst its portfolio of spending across the economy.

Section 2: Contribution towards the Commission's objectives

This section explains how the Commission's energy recommendations contribute towards its four objectives.

Support sustainable economic growth across all regions

The Commission's energy recommendations are likely to have a positive contribution to this objective. Recommendations are expected to substantially reduce spending on energy by households and businesses, driven by the supply of electricity via low carbon sources.

For businesses, lower energy input costs likely increase the efficiency of businesses. This direct boost to productivity can in turn facilitate further investments elsewhere in the economy, such as in new assets or to upgrade capital. For households, lower energy bills mean more disposable income and such a boost to spending power can be expected to increase consumption and raise living standards.

It is likely that there will be local economic benefits across the country following the development of key sites for carbon capture and storage and hydrogen. In focusing on developing major industrial hubs first, there will be specific regional benefits to support existing industries and to encourage new industry into areas which have seen decline or are underperforming, such as north east Scotland, the north east and north west of England and Wales.

Improve competitiveness

The Commission's energy recommendations are likely to have a positive contribution to this objective. Recommendations promoting support for the scale up of new forms of low carbon generation and heating technologies will increase competition with domestic energy markets. Increased competition typically reduces the cost of doing business, reducing the costs for new entrants as well as for incumbents. The role of infrastructure in providing access to decarbonised electricity, hydrogen and carbon capture and storage will allow UK firms to capture market share in global low carbon supply chains, and these technologies have the potential to become price competitive in the medium term.

The recommendations also lower bills and improve the stability of prices, which increases the ability of UK services and manufacturing to stay internationally competitive.

Improve quality of life

The Commission's energy recommendations are likely to have a positive contribution to this objective. Electric heating and renewable energy generation will improve air quality in homes. Making homes more energy efficient reduces the energy demanded to heat them, improving comfort as well as making energy bills more affordable.

Table 3 summarises the most significant impacts of the Commission's energy recommendations by domain as outlined in **Table 1**. The largest impacts are likely to be on health and affordability.

Table 3: Summary of quality of life impacts by domain

Domain	Summary of impacts
Health	The Commission's energy recommendations are likely to have strongly positive impacts through improvements in air quality and the energy efficiency of homes, improving heat retention in cold periods. Replacing gas boilers is directly beneficial for local air quality, particularly in winter, reducing both nitrogen oxides and particulate matter emissions.[12] Phasing out fossil fuel electricity generation (unabated gas) will have a beneficial impact on air quality as combustion of these fuels releases a number of gaseous and particulate air pollutants.[13]
Local and natural surroundings	The Commission's recommendations on planning for Nationally Significant Infrastructure Projects will ensure that projects which fall into this category have clear upfront standards to meet to ensure their impact on the natural and built environment is appropriately and strategically mitigated. This will provide communities with clarity on how the impact of large schemes will be managed. This means any negative impacts from building new energy infrastructure as a result of recommendations should be mitigated. Energy infrastructure can intrude on local and natural surroundings though their visual impact can be mitigated.[14] Pipes and cables can be rerouted underground[15], although electricity transmission pylons, onshore wind turbines and solar farms are notable exceptions. There will be local impacts from recommendations that require building new assets, such as new generation plants, and there may be temporary road disruption from any changes to the gas network (which could also impact connectivity via the road network).
Connectivity	The Commission's energy recommendations are unlikely to materially affect physical or digital connections. Network reliability may improve as energy system investment supports the increase in and nationwide availability of the number of public electric charge points for electric vehicles.
Affordability	Households that spend a larger proportion of their income on energy could stand to benefit the most. The Commission recommends financial support for those on lower incomes and those living in social housing to improve energy efficiency and instal heat pumps or to connect to a heat network. This should lower their upfront and running costs of switching to electrified heating. The Commission's recommended package of support via subsidies and zero per cent financing for heat pumps and energy efficiency installations supports all households in making the transition to low carbon heating more affordable. These measures lower the proportion of income spent on energy by households in the future, as detailed in **Section 4**.

[12] The Royal Society (2021), Effects of Net Zero Policies and Climate Change on Air Quality, p. 62
[13] The Royal Society (2021), Effects of Net Zero Policies and Climate Change on Air Quality
[14] National Grid (2017), Visual Impact Provision; National Grid (2017), Annex to Visual Impact Provision Policy
[15] Geospatial Commission (2023), National Underground Asset Register (NUAR)

Comfort and convenience	Switching to a heat pump will maintain comfort levels in heating. Increasing insulation will also improve comfort levels and reduce heating costs as less energy is needed to heat rooms.[16] Many households and businesses will face some level of inconvenience to install new heating technologies, as 88 per cent of English homes are reliant on natural gas for heating.[17] Interventions required will vary by property, depending on property characteristics and the type of heating appliance installed.[18] The installation requirements of a heat pump would only apply for the initial installation, as these are one off costs and hassle. Replacing a heat pump, which has a similar lifetime to a gas boiler, is fast and straightforward. Recent survey evidence[19] suggests that views on the relative disruptions of heat pumps and hydrogen as a low carbon alternative may not be that different, especially once factors such as provision of networks and coordination of a simultaneous switchover of local areas to hydrogen are factored in.
Employment	The Commission's recommendations propose significant investment in generation and new networks. This will lead to an increase in construction employment to build, upgrade and repurpose the electricity, natural gas, hydrogen and carbon capture networks. Opportunities in these sectors exist both in local industrial clusters and nationwide to link sites up from Grangemouth to South Wales and to Southampton. To decarbonise the buildings sector more installers will be needed due to the scale and pace of roll out of heat pumps recommended. Some estimate that the number of trained heat pump engineers will need to increase nine-fold to meet government's 2028 target.[20] This will increase employment opportunities across all regions, in both urban and rural areas, as the roll out is nationwide.

Support climate resilience and the transition to net zero carbon emissions by 2050

The Commission's energy recommendations have a strongly positive contribution to this objective. Around 80 per cent of the UK's energy demand is currently met by fossil fuels.[21] The recommendations minimise unabated gas use in the economy — predominantly in electricity generation and heating buildings — and significantly reduce carbon emissions. Taking the recommended actions will support the UK in meeting its legally binding climate targets.

[16] Energy Saving Trust (2022), In-depth guide to heat pumps
[17] Department for Levelling Up, Housing and Communities (2022), English Housing Survey Report, 2020-21, p. 14
[18] National Infrastructure Commission (2023), Technical annex: hydrogen heating
[19] Thomas, Pidgeon and Henwood (2023), Hydrogen, a less disruptive pathway for domestic heat? Exploratory findings from public perceptions research
[20] Nesta (2022), How to scale a highly skilled heat pump industry
[21] Department for Energy Security and Net Zero (2023), Digest of UK Energy Statistics

Section 3: Impact on the Commission's fiscal remit

The Commission's recommendations require public capital to support the decarbonisation of buildings, development expenditure for the construction of new carbon capture and storage and hydrogen networks, and support for the initial rollout of engineered greenhouse gas removals. Total public capital investment in energy over the 30 years from 2025 is estimated to be £154 billion.

The recommended fiscal package for decarbonising heating and improving energy efficiency supports the following groups:

- public sector buildings (energy efficiency and heat)
- social housing (energy efficiency and heat)
- homes occupied by households on lower incomes (heat)
- buildings occupied by all other households and small businesses (heat).

Social housing tenants and households on lower incomes will be the greatest beneficiaries of this support to change the way they heat their homes. For all social housing tenants and other households on lower income, the full capital cost of switching to a heat pump or heat network will be covered. For all social housing tenants, the cost of improved energy efficiency will be covered. For all other residential buildings, a subsidy will be provided to cover part of the capital cost of installing a heat pump or switching to a heat network.

Support for the private sector with development expenditure aims to cover a proportion of the cost of front end engineering design studies related to building core networks for carbon capture and storage and hydrogen.

Table 4 shows a forward projection of government capital expenditure to deliver the Commission's recommendations on heat decarbonisation, energy efficiency, new network expenditure and greenhouse gas removals.

Table 4: Fiscal remit impact, average annual expenditure (£ million 2022 prices, 2025-2054)

Source of costs	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Total energy recommendations	3,500	8,100	12,200	4,600	2,100	400
Decarbonisation and energy efficiency	3,400	8,000	12,100	4,600	2,100	400
CCS and hydrogen development expenditure	50	50	0	0	0	0
Greenhouse gas removals	30	20	10	0	0	0

Section 4: Impact on the Commission's economic remit

The energy recommendations in the Assessment will have an impact on the economic remit through consumer bills, expenditure on heat infrastructure and public sector resource expenditure. Households and businesses pay to use energy infrastructure and services through energy bills and in the cost of in-home equipment to heat their homes, such as heat pumps, boilers and energy efficiency measures. The public sector incurs resource costs both to cover energy bills for its own estate and in delivering certain government policies. A recent example of this type of cost is the 2022/23 Energy Price Guarantee which supported all households with their energy bills at a time of rising gas prices.

Going forward resource costs will include the cost of the Commission's recommendation to provide zero per cent financing to households and small businesses for loans to purchase low carbon heat appliances and install energy efficiency measures. It will also cover the cost to government of taking on some of the risk of developing new networks and the recommendation that the policy costs of electricity should be paid for through taxation rather than bills.

In summary, the trajectory of energy expenditure by households is estimated to fall between 2022 and 2054. Gas and electricity prices fall from their 2022 peak and electricity prices continue to fall through to the 2040s. A switch to electrified forms of heating lowers bills for households. These bill reductions are slightly offset by increased investment in the heat infrastructure required to decarbonise homes. Business spending on energy infrastructure will remain broadly similar over the period. Decarbonising the industrial sector requires switching from fossil fuels to a mix of electricity, hydrogen and fossil fuels abated with carbon capture and storage, and large industrial users will pay to use these new networks. Public sector resource costs are likely to fall driven by the removal of the Energy Price Guarantee in 2023, but some of this fall will be offset by the added cost of taking policy costs off the electricity price.

Costs to households and businesses

Under the Commission's recommendations, total household expenditure on energy is estimated to halve between 2022 and 2054 from around £2,200 per average household to less than £1,400 in the 2030s and remain around this lower level until 2054, as shown in **Table 5.a**. Within this expenditure, the proportion spent on electricity and gas bills falls to around two thirds of the total while investment in heat infrastructure, such as heat pumps, increases.

Table 5.a: Economic remit impact, average annual energy expenditure per household (£ per household 2022 prices, 2025-2054)

Category	2022 comparator	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Households	2,240	1,320-1,790	1,120-1,410	1,170-1,430	1,100-1,350	910-1,120	950-1,160
Electricity bill	1,000	420-570	340-430	310-380	280-350	230-280	200-240
Heat bill	950	630-890	510-650	460-560	410-500	380-470	370-450
Heat capital costs	290	270-330	270-330	400-490	410-500	300-370	380-470

Historically a unit of electricity has been more expensive than a unit of gas. The Commission's recommendations support price parity between a heat pump and a gas boiler being achieved on a lifetime basis. Households will go from spending on both gas and electricity to solely using

electricity to power and heat their homes. Trends in household expenditure on energy are affected in three ways:

- **Reduction in household electricity bills.** The Commission's recommendations support a shift away from unabated gas to more renewables and low carbon sources of flexibility. Electricity prices are projected to reduce steadily over time. As electricity demand increases, system costs will increase but these costs are spread over a growing demand base.
- **Increase in household gas bills.** Households will be incentivised to shift away from using fossil fuel boilers to heat their homes, therefore the impact of an increase in gas bills diminishes over time. This may affect the gas price as it could mean recovering costs over a smaller base of demand. The Commission acknowledges this potential impact.
- **Increase in heat capital costs.** Investment in technologies to heat buildings will become a larger proportion of household energy expenditure over the next 30 years as all households will need to switch from a gas boiler to an electrified form of heating. The Commission recommends that government supports this transition with subsidies and zero per cent finance to manage the upfront cost of a heat pump or heat network connection, but households will still need to bear some of the cost.

Lower income households typically spend a higher proportion of their income on energy. The Commission has recommended supporting these households by covering the full cost of heat pumps for these households. **Section 6** has a further discussion of distributional impacts.

Table 5.b shows that businesses' energy expenditure is also estimated to fall to 2054, from nearly £40 billion in 2022 to between £29 and £35 billion annually on aggregate. This includes costs incurred by large industrial users for their use of hydrogen and carbon capture and storage networks.

Table 5.b: Economic remit impact, average annual business energy expenditure (£ million 2022 prices, 2025-2054)

Category	2022 comparator	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Businesses and industry	39,900	27,600-36,100	26,800-32,800	29,100-35,500	30,200-36,900	29,900-36,500	28,700-35,000
Energy bills	37,800	26,400-34,600	25,700-31,500	28,100-34,300	29,400-35,900	29,000-35,500	27,900-34,100
Heat capital costs	2,100	1,200-1,500	1,000-1,300	1,000-1,200	800-1,000	900-1,000	800-1,000

Costs to the public sector

Table 5.c shows the average annual day-to-day ('resource') expenditure by the public sector reducing from 2022 to 2054. The government incurs energy costs to operate its estate which will need to be decarbonised alongside all other buildings. The Commission's recommendations add to government resource expenditure as there is a cost to:

- providing zero per cent financing for households and businesses to cover the remaining capital expenditure to install low carbon heating above the subsidy level and in improving energy efficiency
- covering the policy costs that have previously been included in the price of electricity
- managing underutilisation risk of early hydrogen and carbon capture and storage network development.

Table 5.c: Economic remit impact, average annual expenditure by the public sector (£ million 2022 prices, 2025-2054)

Category	2022 comparator	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Total government energy expenditure	23,300	12,400-12,300	11,900-14,500	5,300-6,500	3,000-3,700	2,600-3,200	2,300-2,800
Government energy bill	2,500	1,700-2,300	1,600-2,000	1,800-2,200	1,900-2,300	1,800-2,200	1,800-2,100
Government resource spend on policy	20,800	10,600-13,000	10,200-12,500	3,600-4,400	1,200-1,400	800-900	600-700

Section 5: Environmental impacts

The Commission measures the environmental impact of its recommendations across three environmental domains: air pollution, biodiversity and water quality. These are three of the themes in the government's 25 year environment plan[22] relevant to the Commission's recommendations. The impact of the energy recommendations on these domains is summarised in **Table 6**.

In addition, the Commission measures the carbon impact of its recommendations. This includes carbon embodied in the construction of infrastructure as well as operational carbon emissions.

Table 6: Environmental assessment of the energy recommendations

Environmental impact	Contribution to net gain
Air pollution	The Commission expects beneficial outcomes for air quality, with reductions in emissions of nitrogen oxides and particulate matter expected from a significant reduction in the use of unabated gas for electricity generation, heating buildings and in powering industry. Hydrogen combustion will still generate certain emissions (nitrogen oxides in particular) but will not generate any particulate matter emissions.[23] Combustion of hydrogen (for generation and industry) will be on a smaller scale than today's combustion of natural gas (for generation, heating and industry) so an overall reduction in air pollution is very likely.[24]

[22] Department for Environment, Food and Rural Affairs (2023), 25 Year Environment Plan
[23] McKinsey (2021), How hydrogen combustion engines can contribute to zero emissions
[24] National Infrastructure Commission (2023), Technical annex hydrogen heating; Aurora Energy Research (2023), The impact of decarbonizing heating on the power system (C)

Environmental impact	Contribution to net gain
Water quality	The move to increasingly renewable generation will reduce the amount of water required for steam-driven turbines and cooling.[25] There will still be water demand from hydropower and future thermal generation (hydrogen or gas with carbon capture and storage), but there will be a gradual decline from today's level of thermal generation.[26] The majority of this water is also returned to the environment.[27] Hydrogen production uses water, with the demands of green hydrogen more significant[28] and the Commission expects this will become the dominant hydrogen production technology. Risks of reduced freshwater availability in the future could be mitigated by using desalinated seawater.[29] Water demand by households would increase if hydrogen were used to heat homes, though the Commission recommends that hydrogen heating is not supported.[30] There is considerable uncertainty in the volume of hydrogen that will be used in electricity generation and by industry and therefore how much water will be needed. The UK lacks a definitive dataset detailing the exact cooling method and water source of all thermoelectric power stations and future generation processes and quantitative estimates have not been included in the Commission's analysis. To mitigate adverse effects, an environmental permit is required where electricity generation activity could pollute the air or water, increase flood risk or adversely impact land drainage. Prior to construction new generation facilities must also undertake an environmental impact assessment. In retiring old generation infrastructure, the potential to repurpose current gas generation sites would also further reduce the local impacts, as access to water would already be in place.

[25] Water is abstracted for cooling at 82 per cent of thermoelectric power stations in the UK. Byers, Hall and Amezaga (2014), Electricity generation and cooling water use: UK pathways to 2050, p. 18
[26] Aurora Energy Research (2023), The impact of decarbonizing heating on the power system (C)
[27] Environment Agency (2012), Water use and electricity generation
[28] Climate Change Committee (2023), Delivering a reliable decarbonised power system, p. 18
[29] Climate Change Committee (2023),The Sixth Carbon Budget - Electricity Generation, p. 33
[30] National Infrastructure Commission (2023), Technical annex: hydrogen heating

Environmental impact	Contribution to net gain
Biodiversity	A significant increase is expected in overall investment in economic infrastructure, meaning the greater construction volumes (of electricity generation, transportation and storage infrastructure) will need to be offset to compensate for any biodiversity loss and ensure losses of natural capital are avoided, minimised and mitigated. From 2025 new nationally significant energy infrastructure will be legally required to achieve biodiversity net gain.[31] The government's Land Use Framework will create an opportunity to consider how land use could be multifunctional[32], for example with technologies such as solar and onshore wind where the amount of land used is typically lower than other generation assets.[33] The land between and underneath panels and turbines — depending on the density and spacing between them — can be used for other activities or rewilded. [34] Decommissioning plants such as unabated gas turbines could allow the site to be used in an environmentally beneficial way. Such actions could offset environmental damage from new infrastructure assets, or construction impacts minimised as these plants are converted to use carbon capture and storage technology over new sites being developed. The Commission's recommendations on planning for Nationally Significant Infrastructure Projects will ensure that projects which fall into this category have clear upfront standards to meet to ensure their impact on the natural and built environment is appropriately and strategically mitigated.

[31] Department for Environment, Food and Rural Affairs (2023), Consultation on Biodiversity Net Gain regulations and implementation: Government response and summary of responses
[32] Food, Farming and Countryside Commission (2022), Proposed Land Use Framework for England
[33] Our World in Data (2022), How does the land use of different electricity sources compare?
[34] Solar Energy UK (2019), The Natural Capital Value of Solar

Section 6: Distributional impacts

This section assesses the distributional impacts of the Commission's energy recommendations to 2050 across three dimensions: income groups, protected and vulnerable groups, and geography.

When analysing the impacts of changing energy spend by households, the Commission considers expenditure on gas and electricity bills, as well as heat infrastructure costs such as heat pumps and boilers. Across all groups spending on energy infrastructure is expected to fall, with savings compared to 2022. This is primarily due to lower electricity unit costs feeding into lower bills, and improved energy efficiency leading to lower energy demand.

Households with the lowest incomes are set to be supported through the heat transition via the Commission's recommendations to subsidise the full cost of installing low carbon heating and improving energy efficiency. Disparities in energy spending across regions is estimated to reduce, with the current largest gap between north west England and London flattening by 2050.[35]

Households sensitive to energy price increases or with higher heating needs will be impacted more, with specific groups detailed in **Table 7**.

Table 7: Distributional impact summary

Dimension	Description
Income groups	Lower income households are set to see the greatest fall in energy spend in proportional terms by 2050 due to the Commission's recommendations. This reflects firstly the impact of the heat subsidy support recommended, which covers the full cost of installing a heat pump or switching to a heat network, and associated energy efficiency upgrades. The second effect is lower electricity unit costs driven by increased renewable penetration in generation. The Commission's analysis shows that there is a 55 per cent fall in the proportion of household spending on energy, for both top and bottom income deciles, as a result of its energy recommendations.
Vulnerable and protected groups	The Commission's recommendations support the full cost of installing heat pumps and energy efficiency for lower income households and those in social housing, representing over one third of households **Age** — older and retired people tend to use electricity and heat more and differently throughout the day to people of working age. The way heat pumps are used (maintaining stable levels of heat) may mean older people do not see as great a change in their heat demand patterns compared to others. **Disabilities** — some people with disabilities and chronic health conditions — some of which are more common in certain ethnicities[36] — need to heat their homes for longer or to higher temperatures and use more electricity for medical equipment.[37]

[35] National Infrastructure Commission (2023), Distribution analysis technical annex, p. 10
[36] Sickle cell disease can cause chronic pain that worsens with colder temperatures and is particularly common in African and Caribbean communities. National Institute for Health Care and Excellence (2021), How common is sickle cell disease?; BBC (2023), Cost of living crisis: Sickle cell families staying in bed for warmth
[37] Regen (2022), Why are disabled people more vulnerable to rising energy costs and what should be done about it?

Dimension	Description
	With falling unit costs of electricity, disparities in the proportion of total household spend going towards energy between these and other groups should reduce over time.
Geographical	Differences between regions in household spending on energy are expected to decrease by 2050. Regional analysis shows that households in the south of England — as one of the warmest and wealthiest regions — generally spend the lowest proportion of their income on energy compared to other regions. By 2050 there may be a significant reduction in regional disparities.

Section 7: Uncertainty

This section presents how robust the Commission's recommendations are to different possible future states of the world based on a set of drivers, and to changes in assumptions. It assesses the degree of confidence in the fiscal and economic remit estimates, and other impacts outlined above, and the reasons for this judgement. These are set out under three risk classifications, as set out in the Commission's managing uncertainty framework.[38]

Table 8: Uncertainty summary

Driver	Classification	Description
Economic growth	Robust	Recommendations are robust to future economic growth expectations since actions required to reach net zero by 2050 are largely independent of different growth rates. It is factored into analysis that energy demand will increase to 2055, so there will be associated rising demand for energy infrastructure services.
Climate change	Robust	Sensitivity analysis when modelling pathways to decarbonise power and building sectors considered a range of more extreme climates and weather conditions affecting electricity demand, peak demand and therefore the level of generation needed.
Technology and behaviour change	Robust	Recommendations require new technology adoption and behaviour change under all scenarios to reach net zero by 2050 and precursory carbon budgets. Heat pumps are an existing technology, widely and increasingly adopted in other European countries.[39] Some proportion of heat pump uptake is included in all heating scenarios modelled.[40] Behaviours around the ways electricity is used throughout the day, through smart devices, flexibility services and a smoothed heating profile from heat pumps are expected to change over time. Investments in these technologies will reliably reduce carbon emissions. For some sectors like production of construction material where decarbonisation is more challenging via electrification, newer technologies such as carbon capture and storage will need to be deployed at scale. Although the cost range is large, a substantive network is a robust investment across a range of future scenarios.
Population and demography	Robust	Population and demographic change have direct impacts on demand for energy. The Commission's recommendations are inherently scalable to different levels of demand due to population and demographic change.

[38] National Infrastructure Commission (2022), Managing uncertainty in the second National Infrastructure Assessment
[39] IEA Global heat pump sales (2023), Global heat pump sales continue double-digit growth
[40] Aurora Energy Research (2023), Decarbonising heating systems (B)

Table 9: Sensitivity summary

Sensitivity	Description
Electricity demand	Costs are sensitive to future levels of electricity demand (for example, how quickly sectors such as heating and transport decarbonise) and in which locations. Upgrades of the electricity network will be needed in parallel with uptake of electric forms of heating and transport. Future household electricity demand levels could vary if there is a faster or slower rollout of low carbon heating, electric vehicle take up or industrial electrification than that assumed in modelling. While core networks of hydrogen and carbon capture are being developed for industrial use, government should ensure that planning for potential future stages of the networks is also in train, using an adaptive approach to manage the uncertainty and stranding risk while minimising the cost of inaction and delay.
Generation mix	Different mixes of low carbon generation technology — wind, solar, nuclear — and lower levels of flexible technologies could lead to the electricity system being more expensive. Comparisons between modelled scenarios show this could be between four to 18 per cent more by 2035, and nearly 20 per cent more by 2050.[41]
Cost of new networks	The costs of deploying new hydrogen and carbon capture and storage networks are uncertain. At present, uncertainty around the scale and location of demand for hydrogen and carbon capture and storage networks means potential developers of pipelines and stores face risks and costs of their assets being underused. Research has indicated that development expenditure costs in these type of infrastructure projects range between two to five per cent of capital expenditure and the range of capital expenditure estimates is even wider. Adopting upper and lower bounds for the costs of these new networks reflects the cost uncertainty in these technologies and is factored into the range shown in **Table 5a** of costs business and industry incur.
Heat technology costs	There is uncertainty around the scale and speed of the reduction in the upfront capital cost of heat pumps. The Commission has adopted a conservative trajectory of heat pump costs falling by 25 per cent by 2050. With industry innovations and accelerated demand, heat pump prices could reduce less or more than this (some estimate a 30 to 40 per cent fall by 2050)[42], offering greater savings from switching from a gas boiler to many households.
Electricity and gas prices	Changes in the sensitivities listed above drive changes in electricity and gas price trajectories, and the costs to households for energy. An increase and decrease of ten per cent of electricity and gas prices from 2035 — after a recommended end of the sale of all new fossil fuel boilers — drive the ranges of household energy bills in **Table 5a.**

[41] Aurora Energy Research (2023), System flexibility in achieving net zero (A) – Annual databook

[42] Element Energy for Committee on Climate Change (2021), Development of trajectories for residential heat decarbonisation to inform the Sixth Carbon Budget, and Nesta (2022), How to reduce the cost of heat pumps pp. 40-41

Transport Impact and Costings

Section 1: Assessment recommendations and outcomes

The Commission has made ten recommendations for transport within the Assessment.[43]

Outcomes

The main outcomes of the Commission's transport recommendations are to improve regional growth and competitiveness in major cities and underperforming regions outside of London and the South East. In addition, the recommendations ensure the transport system can adapt to climate change and decarbonise to support the transition to net zero.

Level of investment

The level of investment supporting the Commission's recommendations is £760 billion (2022 prices) over 30 years from 2025. Much of this spend reflects ongoing maintenance and renewal of the assets, including an uplift for the costs of climate adaptation. Existing commitments such as rail and road improvement projects and expected levels of spend for example by local authorities are also included. There is also an adaptive pot which is available for costed proposals that would be required under specific circumstances.

The following sections focus on the impacts of 'additional' elements of the Commission's recommendations which have the most significant impacts and costs. These are recommendations 17 and 18 which require investing in major urban public transport projects and the implementation of demand management measures as well as recommendation 22 to develop and implement a long term pipeline for road enhancements. Here, these recommendations are referred to as urban and interurban recommendations respectively. These recommendations have the most significant impacts on transport capacity and connectivity, as well as wider impacts which are reported in the relevant section.

Funding and financing

Capital investment in the transport system is largely provided by the public sector through central government grants to transport operators such as National Highways or Network Rail. Local transport is typically funded through a mixture of grants and local authorities' own funding as well as other sources. The recommendations for capital expenditure would be borne primarily by the public sector and are considered within the Commission's fiscal remit. A small proportion of transport infrastructure is privately owned and operated. However, the Commission is not making recommendations relating to this.

[43] National Infrastructure Commission (2023), second National Infrastructure Assessment

Section 2: Contribution towards the Commission's objectives

This section explains how the Commission's transport recommendations contribute towards its four objectives.

Support sustainable economic growth across all regions of the UK

The transport recommendations in the Assessment are likely to make a positive contribution to this objective overall. Providing good transport links between them is a necessary — if not sufficient — condition to improve economic performance in cities and regions that currently underperform.[44]

The Commission's analysis indicates that investing in transport can improve productivity in two mutually reinforcing ways:[45]

- Improving long distance connectivity on the interurban network improves market access, facilitates trade and makes firms more productive.[46]
- Improving urban transport capacity in regional cities alleviates transport constraints, facilitating more trips and supporting future employment growth in city centres. This increases employment density which has agglomeration effects.[47]

The analysis uses proxy measures to capture the economic benefits without expressing them in monetary values. For the Commission's interurban transport recommendations this is measured using connectivity improvements in different regions, while the impact of urban transport recommendations are based on changes in employment density in different types of city — see **Box 1** for details.

Box 1: The Commission's connectivity metric[48]

The baseline connectivity score is based on today's road network. The score for each region is based on the average connectivity score for each built up area within that region. For each built up area, the travel time between it and all other built up areas in the country is calculated, with travel time between places weighted by the potential demand for travel to each place. This means the travel time between bigger, closer places tends to count for more than the travel time to smaller, further away places.

The result is expressed as a ratio of the connectivity to all other places by observed speed versus straight line crow flies speed (50 kilometres per hour). This means that a figure less than one shows that overall demand weighted travel speed is less than 50 km/h to all other places; a score greater than one means demand weighted travel speed is greater than 50 km/h. Connectivity improvements can occur beyond the region where the

[44] National Infrastructure Commission (2021), The Second National Infrastructure Assessment: Baseline Report p.58. National Infrastructure Commission (2020), Growth across regions

[45] Further productivity gains may arise because it is more efficient for places to specialise and trade than to produce a bit of every good, and through the agglomeration benefits (such as increased innovation) that arise from clustering. See wide ranging literature on this topic including: Frontier Economics (2017), Exploring the economic benefits of strategic roads. Report produced for DfT. Laird and Johnson (2021), The GDP Effects of Transport Investments: The Macroeconomic Approach. Krugman and Venables (1996), Integration, specialization, and adjustment. Fujita and Thisse (1996), Economics of agglomeration

[46] Frontier Economics (2017), Exploring the economic benefits of strategic roads. Report produced for DfT

[47] Stansbury, Turner and Balls (2023), Tackling the UK's regional economic inequality: Binding constraints and avenues for policy intervention. Graham and Gibbons (2018), Quantifying Wider Economic Impacts of Agglomeration for Transport Appraisal: Existing Evidence and Future Directions. Graham, Gibbons and Martin (2009), Transport Investment and the Distance Decay of Agglomeration Benefits

[48] Steer (2023), Interurban Connectivity Assessment

investment occurs. London's baseline connectivity is low as the score is based on travel time to the centre of London, which is significantly affected by congestion.

Employment density calculations

Modelling carried out for the Commission assessed transport capacity requirements for cities in England to meet future employment growth in city centres between now and 2055 across a range of capacity scenarios (low, medium and high).[49] This was assessed for a sample of 20 'case study' cities, and then extrapolated to all 54 cities in England excluding London.

Using this, the Commission's analysis estimated the additional city centre employment density in 2055 from meeting capacity requirements in each scenario based on the 20 case study cities, aggregated for cities in each size band (small, medium, large). This compares the 'unconstrained' employment growth compared to a counterfactual of employment growth being constrained by transport capacity.

Employment density in each case is calculated by the ratio of employment to the land area of the city centre. The latter is based on the 'city centre cordon' which is estimated for each case study city. The cordon captures areas of high employment, while also considering the effect of current transport infrastructure and natural boundaries on the geographic extent of the city centre.[50]

Table 10 provides a summary of the connectivity improvements by regions from investing in strategic roads,[51] focusing on sections of the network which have high demand and are underperforming.

The results show variation in connectivity benefits across regions. This is due to two main factors. Firstly, some regions can experience larger or smaller connectivity improvements due to their geography — particularly the distances between built up areas. For example, areas in the South West are relatively spread out compared to the North West where they are closer together. Secondly, regions can benefit from improvements made in other regions. This is the case with London and the South East indirectly benefitting to a greater extent from investments made in other regions.

Table 10: Road investment and connectivity impacts for different portfolios[52]

		Connectivity improvement compared to baseline score	
Region	Baseline connectivity score	Unweighted 'national' portfolio (percentage change)	Weighted 'regional' portfolios (percentage change, low - high range)
London	0.52	+9.0	+8.2 to +9.1
South East	0.85	+8.3	+7.0 to +7.8
South West	1.18	+12.1	+11.5 to +13.8
East of England	0.72	+5.2	+4.2 to +4.5

[49] Steer (2023), Urban Transport Capacity, Demand and Cost: Main Report
[50] Steer (2018), Urban Transport Analysis: Capacity and Cost. City centre cordon definitions are the same as those developed for the first National Infrastructure Assessment
[51] Using connectivity based metrics is different from traditional 'accessibility' based measures which capture changes in market access (i.e. area that is accessible within a certain travel time) in order to estimate the impact of transport improvements. Table 1 provides further explanation of the Commission's connectivity metric. For an example of accessibility based measures see OECD (2020), Roads, market access and regional economic development
[52] Steer (2023), Interurban Connectivity Assessment

East Midlands	0.99	+6.2	+6.3 to +7.1
West Midlands	1.13	+6.3	+6.7 to +7.7
Yorkshire and The Humber	1.11	+6.9	+6.5 to +7.7
North West	1.04	+4.0	+3.7 to +5.0
North East	1.17	+9.9	+10.2 to +13.4

Table 11 sets out the additional employment density benefits that could be achieved by the Commission's urban transport recommendations on investing in public transport and implementing demand management. This analysis indicates that compared to small and medium cities, large cities could achieve the highest economic benefits but also have the widest range due to uncertainty in future travel demand.

The recommendations also propose investment in appropriate public transport modes to maximise potential economic benefits. For example, achieving the highest potential employment density in the largest cities is only possible by investing predominately in tram or rail based projects.[53] Conversely, bus rapid transit projects may be appropriate elsewhere due to the lower cost and flexibility.

Table 11: Aggregate additional city centre employment density in 2055 from meeting urban transport capacity requirements, by city size band *(percentage change, compared to counterfactual of employment growth being constrained by transport capacity)*[54]

City size band	Range of additional employment density (percentage change, low - high range)
Small	+2 to +4
Medium	+4 to +6
Large	+7 to +24

In line with the objective to maintain the economic performance of high productivity regions, the Commission's recommendations include longer term capital settlements for Transport for London — sufficient to enable both maintenance and enhancement of London transport.

There are uncertainties around the costs and benefits of these recommendations, particularly the economic benefits which may vary spatially as they are impacted by future travel demand and the role of agglomeration in cities. See **Section 7** for more details.

Improve competitiveness

The Commission's recommendations are likely to make a positive contribution to this objective overall. The Commission has previously identified three ways infrastructure can contribute to competitiveness.[55] Of these, the most relevant mechanisms are:

- **Access to mobile labour and capital.** The Commission's urban transport recommendations support employment growth in city centres of large regional cities, with agglomeration effects improving productivity.[56] This is mainly relevant to large city regions and regional corridors.[57] In larger cities or smaller cities with strong city centre economies, implementing demand management alongside

[53] Steer (2023), Urban Transport Capacity, Demand and Cost: Main Report. See section 5.1
[54] Commission calculations of employment density benefits. These are derived from the analysis undertaken by Steer, and is based on 20 case study cities which includes a mix of small, medium and large cities
[55] National Infrastructure Commission (2020), Improving competitiveness
[56] National Infrastructure Commission (2020), Improving competitiveness. Areas of high employment density, with many workers located in close proximity, encourages learning by enabling informal communication networks and information spill overs. Urban transport has a key role in supporting this density by increasing the number of commuters who are able to travel into city centres, particularly widening access to larger pool of skilled workers
[57] See previous section and the Commission's previous work as an example: National Infrastructure Commission (2017), Partnering for Prosperity: A new deal for the Cambridge-Milton Keynes-Oxford Arc

complementary investment in public transport should facilitate mode shift and enable more trips into the city centre.[58]

- **Improving access to markets**. The Commission's interurban transport recommendations improve connectivity. This reduces transport costs benefiting freight users and business travellers, and improves market access for firms, making it easier and cheaper to trade within the UK. This also benefits ports and airports, improving market access to other countries benefitting international trade.

Improve quality of life

The Commission's recommendations are likely to have a mixed impact on quality of life with some positive and negative impacts. **Table 12** summarises the most significant impacts of recommendations on transport in the Assessment by domain as set out in **Table 1**.

Table 12: Summary of quality of life impacts by domain

Domain	Summary of impacts
Health	The Commission's urban and interurban transport recommendations are likely to have localised positive and negative impacts on physical and mental health from changing exposure to air and noise pollution from the construction, operation, and use of new transport capacity. In an urban context, any negative impacts may be offset by reduction in road traffic volumes from using road space more effectively and modal shift to public transport (ie reduced noise and better air quality).[59]
Local and natural surroundings	The Commission's interurban recommendations are likely to have a range of localised impacts due to land use change with subsequent losses in ecosystems services.[60] These impacts vary by type of improvement and scheme design.[61] However, delivering biodiversity net gain should mitigate negative impacts and leave ecosystem services better off overall, although some local losses are still possible depending on how net gains are delivered (see **Table 17** for more details).
Connectivity	The Commission's urban and interurban transport recommendations mean households will benefit from better access to the city centre and improved connectivity for long distance travel for a wide range of purposes such as work and leisure.
Affordability	The Commission's urban transport recommendations will increase the cost of driving to the city centre relative to other modes. Implementing demand management alongside complementary investment in public transport should facilitate modal shift and minimise trip suppression overall. For individual households, the overall impact on affordability depends on whether public transport can provide a genuine alternative to the car for those same car journeys based on time, financial cost, quality and convenience. A more efficient and reliable public transport

[58] Steer (2023), Urban Transport Capacity, Demand and Cost: Main Report. See sections 6.15 and 6.18
[59] Steer (2023), Urban Transport Capacity and Demand Analysis: Demand Management Report. See section 1.19. Department for Transport (2022), TAG Unit A3: Environmental Impact Appraisal. See section 2.1 and 3.1 for a summary of key air and noise pollution impacts
[60] National Infrastructure Commission (2021), Natural capital and environmental net gain
[61] Steer (2023), Urban Transport Capacity, Demand and Cost: Main Report. Tables 5.5, 5.6 and 5.7 provide infrastructure requirements for bus rapid transport, light rail and rail, and the thresholds where line extensions or new lines are required to facilitate extra services. In general, land take for upgrading and building new strategic roads is likely to be more than new fixed infrastructure required for increasing public transport capacity

	system, with more efficient use of road space, should reduce the total costs to transport users in aggregate. However, the effects for different trips are likely to vary depending on local circumstances, and some journeys may be more costly (time or financial cost) resulting in some households either paying the cost, travelling elsewhere or choosing not to travel at all.[62]
Comfort and convenience	The Commission's recommendations mean households are likely to benefit from faster urban and interurban journeys. This is from more efficient use of road space in cities,[63] and from connectivity improvements to underperforming parts of the interurban network (see **Table 10**).
Employment	The Commission's urban transport recommendations facilitate more trips into city centres and enable higher employment growth where selected cities are constrained by their transport networks. This increases employment opportunities in city centres. However, for the interurban transport recommendations there is some uncertainty about the spatial impacts of improving connectivity. This is set out in **Section 7** in more detail.

Support climate resilience and the transition to net zero carbon emissions by 2050

The Commission's analysis indicates that its transport recommendations have a positive contribution to this objective.

Domestic transport produces around a quarter of carbon emissions in the UK and is the UK's largest emitting sector, with the majority of this coming from road vehicles.[64] The Commission's recommendations recognise that credible and adaptive plans to decarbonise the road network are necessary in order for road investments to be compatible with government's climate targets, and to reduce the risk these are not met.[65]

The Commission's analysis assesses the carbon impact from construction and use of infrastructure resulting from its recommendations. The analysis indicates the scale of these impacts are significantly less than the scale of change required to reduce overall emissions from transport and support the transition to net zero. See **Section 5** for more detail.

Finally, the Commission has assumed an uplift in maintenance and renewal spend to invest in climate adaptation measures. See **Section 3 and 4** for more detail.

[62] Steer (2023), Urban Transport Capacity, Demand and Cost: Main Report. See sections 6.15 and 6.18
[63] Steer (2023), Urban Transport Capacity, Demand and Cost: Main Report. See sections 6.19
[64] Department for Transport, Transport and environment statistics: Autumn 2021 and Transport and environment statistics 2022
[65] Department for Energy Security and Net Zero (2023), Carbon Budget Delivery Plan

Section 3: Impact on the Commission's fiscal remit

Total capital investment in transport over the 30-year period from 2025 would be in the order of £760 billion of core spending as shown in **Table 13**.

The second Assessment and these impacts and costings have been undertaken on the basis of delivery of the Integrated Rail Plan for the North and the Midlands including High Speed 2 from Euston station in London to Manchester via Birmingham. The Commission's estimates for the costs of the Integrated Rail Plan include HS2 phases 2a, 2b and East in 2022 prices. On 4th October, government announced that High Speed 2 phases 2a and 2b, as proposed in the Integrated Rail Plan, will not go ahead.[66] Instead, the money would be allocated to other transport projects including rail. Pending full costings for the specific alternative plans, the Commission has retained the cost of phases 2a, 2b and East in the fiscal remit.

Interurban Transport

The total expenditure for interurban transport over the 30 years is around £400 billion.

- Rail investment includes capital spend on maintenance and renewals as well as enhancements. The fiscal remit includes spending allocations for renewals at today's level of investment with an uplift of up to approximately 20 per cent[67] for investment for climate adaptation. This is split equally between core and adaptive spend. Rail investment also includes allocations for the completion of enhancement projects in progress — such as projects in the Integrated Rail Plan for the North and Midlands (see note above on the Integrated Rail Plan) and East West Rail — and provisions for additional rail improvements on other small to medium priorities through a long term pipeline and five year delivery programmes. Spend is also allocated for improvements to the rail network to support its decarbonisation, this is included within the additional decarbonisation measures line.
- Road investment includes capital spend on renewal of the Strategic Road Network as well as enhancements across both the Strategic and Major Road Networks. The provision includes an uplift for climate adaptation in the same proportion as described above for rail.

Urban and Local Transport

The total expenditure for local and urban transport and decarbonisation over the 30 years is around £360 billion.

- Local transport includes a mixture of expenditure from central government and self-funded by local authorities. Together, this includes total expenditure of £240 billion over the 30-year period. This represents an increase to a total of £8.0 billion per year on local transport, excluding expenditure made by the Greater London Authority. This includes both devolved budgets to Local, Combined and Mayoral Authorities as well as self-funded expenditure. This will be spent on asset maintenance and renewal, enhancements to public transport, active travel and local roads as well as enabling infrastructure to support new developments and housing. This uplift includes government commitments such as an additional £1.45 billion annual average investment in the first two rounds of the City Region Sustainable Transport Settlements[68] and investment in enabling infrastructure to unlock new housing sites. As is the case with interurban transport, the

[66] Department for Transport (2023), Network North
[67] In HM Government (2022), Third National Adaptation Programme, the Department for Transport have been allocated an action to develop a transport adaptation strategy to be consulted on by the end of 2023. Pre-empting this work, we have assumed that up to 20 per cent additional spend on maintenance and renewal may be required for climate adaptation. This is split across core and adaptive spend in the fiscal remit for the second Assessment equally. This assumption will need to be revisited once the work being taken forward by the Department concludes and more is known about different investment levels and resultant resilience standards
[68] HM Treasury (2023), Spring Budget 2023

provision includes an uplift for climate adaptation in the same proportion as described above.

- Provision is made for continued investment to address the local roads maintenance backlog in the next decade.
- Provision is made for £22 billion investment for major transport projects in cities from 2028 to 2045.
- Provision is made for spending on transport in London. This reflects Transport for London's Long Term Capital Plan with a focus on protecting core assets and service renewals to maintain the performance and reliability of the public transport network in the 2020s, with spending on new enhancements and extensions to increase the connectivity of the network in the 2030s (for example, the Bakerloo line extension to south east London). It also includes an adaptive provision for the potential development of a large scale improvement from 2040 onwards should this prove necessary.
- Both the core and the adaptive provisions include an allocation for additional spending on decarbonisation of the transport system. It is important to note that this is spending in addition to that which is already contained within individual budget lines — for example enhancements to public transport systems in the local authorities devolved budgets line will support decarbonisation. The core includes elements where investment is needed, whereas the adaptive provision covers investment where it would be required under specific circumstances — for example if private vehicle owners do not switch to zero-emission vehicles as fast as predicted.

Table 13: Fiscal remit impact, average annual expenditure (£ million 2022 prices, 2025-2054)

Source of costs	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Total transport recommendations	27,850	28,000	27,000	26,100	22,000	21,700
Interurban						
Road enhancements	2,900	2,800	2,800	0	0	0
Road renewals	1,500	1,700	1,700	0	0	0
Rail enhancements	1,800	1,700	1,700	0	0	0
Rail renewals	4,000	4,400	4,400	0	0	0
Strategic transport	0	0	0	11,100	11,100	11,100
Integrated Rail Plan and successor schemes	6,100	4,300	3,300	1,900	0	0
Local and Urban Transport						
Local Authorities Devolved Budgets	8,000	8,000	8,000	8,000	8,000	8,000
Local roads backlog	600	600	0	0	0	0
London	2,500	3,400	3,100	2,900	2,600	2,600
Urban major projects	50	700	1,700	2,000	0	0
Decarbonisation						
Additional decarbonisation measures	400	400	300	300	300	0

All spending in this section is gross public sector capital investment and comprises both local and central government spending.

Section 4: Impact on the Commission's economic remit

The cost of the recommendations in the Assessment for transport relate mainly to capital investment. This is for the ongoing renewal of existing infrastructure as well as the construction of new assets as set out in the **Section 3**. Additionally, households and businesses pay to use transport infrastructure and services, for example through fares and fuel costs. The public sector also incurs resource costs for operating and maintaining the infrastructure. The effects of transport recommendations on the costs to households, businesses and the public sector are considered in this section.

In summary, the trajectory of total costs to households and business are estimated to remain broadly similar from today to 2050-54. Public sector costs are likely to slightly increase driven by a marginally larger transport network to maintain and operate than today. Average costs to households fall over the period — owing to cheaper running costs of zero emission vehicles — with aggregate spending levels broadly flat due to housing and population growth offsetting cost reductions for an average household.

Costs to households and businesses

The Commission estimates that total household expenditure on transport could remain broadly flat between 2022 and 2050-54 — £83 billion in 2022 to £75 to 92 billion in 2050-54 — as shown in **Table 15**. Although less expense at the individual household level is expected, an increase in the size of the population offsets this reduction and results in a subtle increase in aggregate expenditure. A similar pattern is seen for business expenditure on transport, £84 billion and £77 to 94 billion over the same time.

Costs per household fall from £3,500 in 2022 to between £2,510 and £3,070 in 2050-54. This is largely due to the reduction in costs associated with the transition of the vehicle fleet to zero emission vehicles and the lower running costs associated with this. Spending on public transport fares is forecast to slightly increase, attributable to modal shift to public transport in major cities. However, the potential increases accounted for here are likely offset by a reduction in car use.

Table 14: Economic remit impact, average annual household and business transport expenditure (£ million 2022 prices, 2025-2054)

Category	2022 comparator	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Impact on household transport costs	83,100	73,700-88,900	74,400-90,900	75,000-91,600	75,400-92,100	75,200-91,700	75,200-91,700
Average impact per household	3,500	3,010-3,630	2,840-3,470	2,690-3,280	2,610-3,180	2,550-3,100	2,510-3,070
Impact on business transport costs	84,300	76,500-90,900	77,000-94,100	77,800-95,100	77,600-94,800	76,900-94,000	76,900-94,000

Costs to the public sector

It is expected that recommended new enhancements to interurban, urban and local transport networks would largely be improvements to the existing asset stock and as such would have a marginal effect on government resource costs. Entirely new infrastructure such as a new urban tram or rail line or a new road link may have a proportionately larger effect on resource costs.

Current operational spend on transport is in the order of £14 billion per year and could be between £13 to £16 billion by 2050-54. This includes spending on items such as staff pay and concessionary support on local and strategic roads, public transport, railways and other transport (such as maritime, ports or aviation). The Commission's analysis suggests costs of implementing a portfolio of road enhancements similar in scale to the Commission's recommended portfolio, may constitute an annual increase of around £180 million in public sector operational cost by 2055.

Additionally, the recommendations for new public transport capacity in cities to will likely require expenditure to operate and maintain. This would be offset against ticket sales and would require approximately £165 million of subsidy (based on typical levels of subsidy for public transport). The true costs will vary depending on future patronage and the infrastructure built which will be a decision for cities pending scheme development, planning and more detailed analytical work.

Demand management measures could generate revenue for local authorities to reinvest in transport, depending on the nature of the scheme. A workplace parking levy in a large city could generate between £10 million and £35 million each year. A congestion charge could similarly generate and between £20 million and £60 million each year. The precise nature of any scheme and therefore any costs or revenue associated with it are a decision for cities and no assumptions on likely revenue have been included in the economic remit.

Operational spending on rail could increase over the period covered by the second Assessment following delivery of the government's current commitments although fare revenue may offset this in part or full.

The Commission has also undertaken analysis to examine the costs of additional investment in the rail network to achieve net zero emissions by 2050. The approach is a mixture of expenditure on electrification infrastructure and rolling stock — which is accounted for in the fiscal remit — with any residual emissions being removed through greenhouse gas removal technology where it is more cost effective to do so. There is uncertainty about the likely cost of greenhouse gas removal technology and the precise costs of investment in the rail network itself. This results in uncertainty about the right proportion of spend between capital investment in the network and operational expenditure on greenhouse gas removal technology. It has been assumed the annual costs of greenhouse gas removals for residual emissions from the rail sector may be in the order of £180 million per year by 2050 rising from around £100 million per year in 2040.

Table 15: Economic remit impact, average annual expenditure by the public sector (£ million 2022 prices, 2025-2054)

Category	2022 comparator	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Government resource expenditure	14,100	12,700-15,500	12,700-15,500	12,800-15,600	12,900-15,800	13,100-15,900	13,200-16,000

Section 5: Environmental impacts

The Commission measures the environmental impact of its recommendations across three environmental domains: air pollution, biodiversity, water quality. These are three of the themes in the government's 25 year environment plan[69] relevant to the Commission's recommendations. The impact of the transport recommendations on these domains is summarised in **Table 16** where the net effects are estimated to be positive.

In addition, the Commission measures the carbon impact of its recommendations. This includes embodied carbon in the construction of infrastructure as well as operational carbon emissions.

Table 16: Environmental assessment of the transport recommendations

Environmental impact	Contribution to net gain
Air pollution	The Commission expects beneficial outcomes for air quality from a significant reduction in air quality emissions from zero emission vehicles. Benefits will also be realised by mode shift towards public transport in urban areas. The scale of mode shift would likely be increased with demand management measures in place. There could be a relatively small element of additional air pollution created by induced demand from road enhancements and associated with construction of road, rail and urban improvements. The nature, location and scale of these will depend on the specific circumstances of the improvement projects. These effects are set against expectations that background improvements to air quality will continue as the fleet modernises. This will reduce emission levels overall in line with recent trends. Nitrogen dioxide (NO_2) emissions fell to 23.6 micrograms per cubic metre ($\mu g/m^3$) in 2022 at the roadside[70] and particulate matter (PM_{10}) has also seen a long-term decrease in levels at roadside, however they have remained relatively stable since 2015.[71] A shift to electric vehicles won't eliminate all emissions from transport as non-exhaust emissions will persist,[72,73] for example brakes and tyres emit particulate matter although notable reductions in NO_2 emissions from less combustion would be expected.
Water quality	The recommended approach to strategic management of the road and rail estates should help to deliver better outcomes overall for water quality and the application of the careful and considered design of new enhancements to the routine renewals and management of the rest of the network can support widespread improvements in outcomes by reducing runoff and subsequent impacts to the aquatic environment. There may be localised negative effects on water quality from run off due to increased transport use. However, this would be offset by wider improvements in the vehicle fleet which results in lower average run off per vehicle. The scale of this will depend on the specific circumstances

[69] Department for Environment, Food and Rural Affairs (2023), 25 year Environment Plan
[70] Department for Environment, Food and Rural Affairs (2023), Nitrogen dioxide (NO2)
[71] Department for Environment, Food and Rural Affairs (2023), Particulate matter (PM10/PM2.5)
[72] OECD (2020), Non-exhaust Particulate Emissions from Road Transport
[73] Air Quality Expert Group prepared for Department for Environment, Food and Rural Affairs; Scottish Government, Welsh Government; and Department of the Environment in Northern Ireland (2019) Non-Exhaust Emissions from Road Traffic

Environmental impact	Contribution to net gain
	of the improvement projects, travel patterns and the location relative to aquatic environments.
Biodiversity	It is a legal requirement for new infrastructure to provide biodiversity net gain. Route selection, considered design, careful management of habitats and improving habitat connectivity can all help to provide this improvement. In addition to making improvements associated with enhancement projects, effective biodiversity management of the entire soft estate can help to maximise the impact of investment in biodiversity improvement at the scale of the whole network. Building of new infrastructure, such as new road schemes, is likely to have localised impacts due to land use change with associated losses in ecosystems services.[74] These impacts may vary by location and scheme design. However, delivering biodiversity net gain should mitigate negative impacts and leave ecosystem services better off overall, although some local losses are still possible depending on how and where biodiversity improvements are delivered. The Commission estimates that enhancements of a similar scale to the proposed road portfolio would need sufficient investment to ensure that a biodiversity improvement greater than 8,000 to 10,000 biodiversity units[75] is provided. Urban transport enhancements are unlikely to have significant effects as land use change is likely to be from developed or brownfield to transport. Delivering biodiversity net gain should mitigate any negative impacts.

Carbon impacts

To comply with the Sixth Carbon Budget, emissions from surface transport will be required to fall from about 110 megatonnes of carbon dioxide equivalents ($MtCO_2e$) in 2021 to around 50 $MtCO_2e$ as indicated by the government's Carbon Budget Delivery Plan — representing a decrease of over half.[76] The Commission's recommendations recognise that investing in enhancements needs to be compatible with decarbonisation targets. Increased monitoring and remedial action will help to reduce the risk of missing interim emissions targets. In the remainder of this section the effects the Commission's other transport recommendations could have on this baseline are described.

The impacts fall into two main areas: induced demand and other changes in transport demand, and 'embodied' carbon from construction. The Commission's analysis indicates that the scale of these impacts is significantly less than other drivers of demand and background changes brought on by the net zero transition.

Induced demand: Improved road connectivity can contribute to increasing traffic volumes by inducing demand for travel on the improved roads that would not otherwise have happened.[77] The Commission's analysis shows that for interurban enhancements this is much

[74] National Infrastructure Commission (2021), Natural capital and environmental net gain
[75] A biodiversity unit is a habitat based approach used to assess an area's value to wildlife. Department for Environment, Food & Rural Affairs (2021), Biodiversity metric: calculate the biodiversity net gain of a project or development
[76] HM Government (2023), Carbon Budget Delivery Plan
[77] Department for Transport (2018), Latest Evidence on Induced travel demand: an evidence review; Transport for Quality of Life (2020), The carbon impact of the national roads programme; Office for Rail and Road (2017-21), Annual Assessments of National Highways/Highways England 2017-2021; and WSP (2018), Latest evidence on induced travel demand: An evidence review

less (~0.6 to 1.3 per cent)[78] than the potential growth in traffic demand from a range of drivers including economic and population growth (between 10 and 28 per cent 2022-2035).[79] A monitoring and review regime for transport decarbonisation is recommended in the Assessment alongside carefully designed adaptive policies – this should be developed taking account of any potential impacts of induced demand.

Other changes in transport demand: The Commission expects that urban transport recommendations may elicit modal shift and changing patterns of demand in turn affecting the carbon intensity of these journeys. Although not quantified, it is expected this would reduce emissions from transport usage by moving travel from private vehicles to public transport and active travel.

Construction emissions: estimated emissions from construction and maintenance activities on the strategic road network (motorways and major A-roads) was 0.73 $MtCO_2e$ in 2020, of which around half were from key materials — concrete, asphalt and steel.[80] There are plans in place to reduce emissions from construction activity in the transport sector, for example National Highways aim to have zero emissions from construction and maintenance by 2040.[81] Based on current construction practices the Commission's analysis indicates that the potential construction emissions from road enhancements, as recommended, is 0.46 $MtCO_2e$. This figure is likely to be an overestimate as new construction practices can be expected to have lower carbon intensity than today.

Rail emissions

1.5 $MtCO_2e$ of emissions were from rail (1.4 per cent of surface transport total) in 2022.[82] Rail decarbonisation can be achieved through a combination of electrifying railway infrastructure and changing the rolling stock operating on the network, primarily to battery or hydrogen.[83] The Commission proposes these are reduced over time through a combination of infrastructure investment (eg rolling stock and electrification) and use of Greenhouse Gas Removal technology for residual emissions where this may be more cost effective than investment in more traditional infrastructure solutions.

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[78] The 2018 Department for Transport literature review found that road enhancements may increase national traffic volumes by around 0.2 per cent for each one per cent increase in capacity; more recent estimates (Transport for Quality of Life 2020) find a two per cent year on year growth in specifically on the improved road corridors. Capacity increases on the Strategic Road Network as a result of road building in 2017-20 amounted to approximately 0.4 per cent per annum (Office for Rail and Road (2017-21), Annual Assessments of National Highways/Highways England 2017-2021. The upper end estimate is calculated on a doubling of the year on year growth rate to 4 per cent for improved parts of the network

[79] Department for Transport (2023), Assumed levels of road traffic and percentage of road traffic from zero emission vehicles, in decarbonising transport upper and lower bound scenarios. Commission analysis of the growth rates in the upper and lower bound scenarios. Department for Transport (2023), Additional information on assumptions used to develop decarbonising transport scenarios. Sets out the assumptions underpinning the low and high traffic scenarios, which feed into the upper and lower bound scenarios

[80] National Highways (2021), Net zero highways: our 2030 / 2040 / 2050 plan; National Highways (2022), Net zero highways: our zero carbon roadmap for concrete, steel and asphalt. Estimated emission from all construction activities are 734,000 tCo2e, of which 373,000 tCo2e are from concrete (217,200 tCo2e), steel (78,500 tCo2e) and asphalt (77,300 tCO2e)

[81] National Highways (2021), Net zero highways: our 2030/2040/2050 plan

[82] Committee on Climate Change (2023), Progress in reducing emissions: 2023 Report to Parliament

[83] Network Rail (2020), Traction Decarbonisation Network Strategy

Section 6: Distributional impacts

This section sets out the main distributional impacts of the Commission's recommendations across three dimensions: income groups, geography, and protected and vulnerable groups. **Table 17** sets this out for each dimension.

Table 17: Distributional impact summary

Dimension	Description
Income groups	All income groups will benefit from improvements in transport capacity and connectivity. Trade benefits from improved interurban connectivity may be passed onto households via lower prices of goods and services or higher wages.[84] However, some income groups are likely to benefit more than others in proportion to their existing use. For example, improving transport capacity into city centres and improving road connectivity would disproportionately benefit middle and high income households who travel more by road and spend more on public transport. The cost and time impact of demand management will be in proportion to existing travel use. This means most of the negatively impacted users will be from households from higher income groups. Acute impacts are possible for lower income households that rely on the car for most journeys — but because such households also tend to take fewer journeys by car the number of impacted households is likely to be relatively lower.[85] All households may benefit through growth in the wider local economy as a result of transport improvements — although the distribution of winners and losers depends on spatial impacts (see **Section 7** for more details).
Vulnerable and protected groups	All groups with protected characteristics will benefit from improvements in transport capacity and connectivity improvements. However, some groups benefit more than others reflecting the overlap between geography and income, based on current differences in transport use. For example, improvements in urban transport will benefit the working age population who commute into city centres and younger people who mostly live in cities. Lower income households which intersect with protected characteristics such as race, tend to rely more on buses. However, middle and higher income earners who tend to travel more by public transport overall (and tend to travel greater distances by rail) also tend to be from White British backgrounds. In addition, any new infrastructure should be designed to modern standards and in line with the Commission's design principles that will maximise accessibility.[86] However, there are opportunities to address the more significant issue of the historic legacy of inaccessible design. This could have a larger impact on improving accessibility in the long term which would benefit those with mobility issues which often overlaps with other protected characteristics (eg disabled people or

[84] Rietveld and Bruimsma (1999), Is Transport Infrastructure Effective? See section 3.2 as an example
[85] Steer (2023), Urban Transport Capacity and Demand Analysis: Demand Management Report
[86] National Infrastructure Commission (2020), Design Principles

Dimension	Description
	older people). This could be taken into account in new approaches to renewals and upgrades with these objectives in mind, rather than straightforward maintenance.
Geographical	The majority of the capacity and connectivity improvements and associated wider (ie economic) benefits are to regions and regional cities outside London. These are also places which are not achieving their productivity potential, which is contributing to the overall disparities between regions. Some regions may benefit more than others. This is partly due to where the improvements are targeted (eg large cities with transport constraints on employment growth), and other factors such as geography and the proportion of business in tradeable sectors who would benefit from lower transport costs (see **Section 2** for more details).

Distributional gaps in transport use

Many of the impacts set out in **Table 18** directly relate to distributional gaps in transport use. Transport, compared to other infrastructure services, offer very different levels of service to different population groups. The Commission's analysis has considered the evidence on how different groups experience transport services today before assessing the impacts of its proposals.

The key evidence on distributional gaps is set out below by income groups, geography, protected and vulnerable groups.

Income groups

In general, total spending on transport increases as household income increases. The proportion of household spending on transport also increases with income – around 7 per cent of expenditure for lower income households, rising to 9 to 11 per cent for the higher income households.[87] Of this, lower income households spend a higher proportion on private transport (eg car) compared to public transport. As household income increases the proportion spent on public transport increases, as does car ownership.[88]

Wealthier households are also more likely to live in rural areas where car travel is more common. Similarly, household income is positively associated with commuting distance. Contrastingly, those on lower incomes tend to live in urban areas and travel less than those on higher incomes.[89]

There are also differences in trip making by mode. Lower income households tend to travel less frequently by car and make shorter trips. By contrast, higher income households tend to travel more frequently and at greater distances. Those in professional occupations similarly travel greater distances.[90] On public transport, higher income households travel significantly more frequently by rail compared to lower income households. However, the relationship for bus travel is the opposite – lower income households take the bus significantly more frequently than high income households.[91]

Geography

[87] Commission calculations based on ONS Living Cost and Food Survey data
[88] Commission calculations based on ONS Living Cost and Food Survey, and Department for Transport National Travel Survey
[89] National Infrastructure Commission (2022), Quality of life
[90] HM Treasury analysis of National Travel Survey data, based on three years of data between 2016 and 2018
[91] Ibid

Transport usage in England varies across geography.[92] Public transport is most widely used in London, alongside bus usage being more prevalent in the North of England, and rail trips most concentrated in the East and South East. Car travel is more frequent for households living outside of London and South East in general.[93] Households outside of London tend to spend a higher share of their income on transport (around 9 to 10 per cent compared to 7.5 per cent).[94] Rural households tend to make more long distance journeys than urban households, reflecting the greater distances travelled required to access employment, services and amenities.[95]

Protected and vulnerable groups

There are disparities in how transport is experienced between and within protected groups.[96] **Table 18** summarises these for selected protected characteristics. The evidence set out here is in addition to disparities in experience on the basis of personal safety which impacts people on the basis of disability, sex, gender identity, religious beliefs, race and sexual orientation.[97]

Table 18: Summary of key disparities in transport use and experience

Protected characteristic	Summary
Age	• Travel use and patterns varies within the working aged population (16-64 year olds) and older people (aged 60 and older), including modal specific differences on bus and rail.[98] • The challenges for younger and older people are different too. Older people are more likely to have a disability or long-term health problem that can affect their ability to use transport, particularly the car. The key issue for younger people is affordability of public transport to access work and other activities.[99]
Disability	• Across all modes disabled people tend to make less trips on average and travel shorter distances compared to those with no mobility difficulties.[100] • This reflects numerous causes, such as differences in accessibility which are a key obstacle to use, and that there are large variances in a person's travel patterns depending on their disability and its severity.[101] In addition, the employment rate for disabled people (52.6 per cent in 2022) is significantly lower than non-disabled people (82.5 per cent) which impacts purpose and distance of travel.[102] • Where people are unable to rely on public transport either due to structural barriers or because of geographical location, they are likely to increasingly rely on more expensive services such as taxis and private hire vehicles (PHVs) – affecting the affordability of travel.[103]
Race	• Travel use and patterns vary between ethnic groups, with differences in disparities by mode. • Some of these differences may be driven by the intersectionality of race with income and geography. For example, middle and high income

[92] HM Treasury analysis of National Travel Survey data, based on three years of data between 2016 and 2018
[93] Ibid
[94] Commission calculations based on ONS Living Cost and Food Survey data
[95] Chatterjee et al (2019), Access to Transport and Life Opportunities
[96] Equalities and Human Rights Commission, Protected Characteristics. As defined by the Equalities Act
[97] Mott MacDonald (2020), Future of Transport - Equalities and access to opportunity. Rapid evidence review
[98] HM Treasury analysis of National Travel Survey data, based on three years of data between 2016 and 2018
[99] Mott MacDonald (2020), Future of Transport - Equalities and access to opportunity. Rapid evidence review
[100] HM Treasury analysis of National Travel Survey data, based on three years of data between 2016 and 2018
[101] Mott MacDonald (2020), Future of Transport - Equalities and access to opportunity. Rapid evidence review
[102] Department for Work and Pensions (2023), Employment of disabled people 2022
[103] Mott MacDonald (2020), Future of Transport - Equalities and access to opportunity. Rapid evidence review

Protected characteristic	Summary
	households who make more trips by car and rail tend to be from White British/other backgrounds.[104] By contrast, a higher proportion of households from Black, Asian and Mixed Ethnic backgrounds live in densely populated urban areas and are more reliant on public transport to access employment. These households are also less likely to have access to a private car.[105]
Sex	• Differences in travel use and patterns vary by sex, as well as experience of the transport network overall (eg journey purpose, safety). • For example, females take more bus journeys than males, but travel less far per journey than males. Males and females take a very similar number of trips by car, but men tend to travel further distances.[106] • Aspects of the transport system are biased towards commuter journeys into city centres (ie radial journeys), and disadvantage non-radial journeys including multipurpose travel (which requires trip-chaining) which is done by carers who tend to be women.[107]
Pregnancy and maternity	• There are differences in the experience of transport networks. Some of the key challenges relate to the availability of public transport for parents or expecting parents, and limitations in transport choice particularly for parents with young children. • Convenience and perceived safety play a role too. Where private transport is available this is a preferred method, especially where journeys are unplanned and unexpected.[108]

[104] HM Treasury analysis of National Travel Survey data, based on three years of data between 2016 and 2018. Department for Work and Pensions (2022), Ethnicity facts and figures – income distribution. Presents percentage of households in each income quintile by ethnicity, before and after housing costs. Data shows that certain ethnic groups have disproportionately more households in lower income groups and less in higher income groups (Black, Pakistani, Bangladeshi, Other). Some ethnic groups have similar proportions of households in each income group (White, White British, Indian, Chinese).
[105] Mott MacDonald (2020), Future of Transport - Equalities and access to opportunity. Rapid evidence review
[106] HM Treasury analysis of National Travel Survey data, based on three years of data between 2016 and 2018
[107] International Transport Forum (2021), Transport Innovation for Sustainable Development: A Gender Perspective
[108] Mott MacDonald (2020), Future of Transport - Equalities and access to opportunity. Rapid evidence review

Section 7: Uncertainty

Table 19 presents how robust the Commission's recommendations are to different possible future states of the world based on a set of drivers and to changes in assumptions. It assesses the degree of confidence in the fiscal and economic remit estimates and other impacts outlined above as well as providing reasons for this judgement. These are set out under three risk classifications as set out in the Commission's managing uncertainty framework.[109]

Table 19: Uncertainty summary

Driver	Classification	Description
Economic growth	Robust	Recommendations are robust to higher and lower economic growth. For example, investment in major urban transport projects caters for a range of scenarios where employment growth in city centres is higher or lower, which impacts future travel demand and capacity requirements. On road investment, the approach prioritises schemes on sections of the network which have high demand and are underperforming. In the event of lower growth only the highest priority schemes would be delivered, while more schemes may be in scope under a higher growth scenario. For transport decarbonisation, the adaptive approach is similarly robust to higher or lower future traffic volumes.[110]
Climate change	Hedge	The recommendations include a 'hedge' in case higher spending is necessary to make infrastructure assets more resilient to increases in global average surface temperature, and if further policy measures are needed to meet decarbonisation targets on domestic transport.
Technology and behaviour change	Robust	Recommendations are robust to behaviour change which may affect the business case for long term transport investment. These account for and mitigate the significant uncertainty on future levels of demand following the covid-19 pandemic and increased substitution of some journeys with digital technology. This has seen a decline in commuting into city centres and business travel which has not recovered to pre pandemic levels, although road travel and freight volumes have recovered.[111] Recommendations are robust to changes in technology. The adaptive approach to decarbonisation is robust to technological uncertainty which may drive different emissions trajectories from the remaining fleet of petrol and diesel vehicles. The Commission's analysis estimated that the high uptake of connected and autonomous vehicles (CAVs) could deliver a similar connectivity improvement to conventional investment

[109] National Infrastructure Commission (2022), Managing uncertainty in the second National Infrastructure Assessment
[110] Department for Transport (2023), National road traffic projections 2022. Report sets out how different economic growth assumptions impact traffic growth
[111] Steer (2023), Urban Transport Capacity, Demand and Cost: Main Report. Department for Transport (2022), National Travel Survey data Table TS0403: Average number of trips, miles and time spent travelling by trip purpose, England: 2002 onwards. Department for Transport (2023), Domestic transport use by mode: Great Britain, since 1 March 2020

Driver	Classification	Description
		in upgrades and new roads.[112] Higher than expected uptake of technology may reduce the business case for some enhancements or may change the focus of that enhancement spend. However, achieving these improvements in reality is subject to considerable uncertainty (eg it may require enabling infrastructure on motorways and major A roads to support higher speeds). An integrated strategy should monitor causes of and respond to emergent trends, reviewing the longer term pipeline as necessary. The Commission's analysis also assessed the impact of higher CAV uptake in urban areas which indicates potential for a small, but not transformative uplift in road capacity — though net impact on capacity would depend on whether CAVs affect demand for driving which was not assessed.[113]
Population and demography	Robust	Recommendations are robust to higher and lower population growth as this changes the funding available and the strength of the business case, altering investment accordingly. For example, investment in major urban transport depends on growth and distribution of working age population. Similarly, for interurban enhancements scenarios where there is lower population growth may reduce the need for investment as this affects future traffic growth.[114]

Table 20: Sensitivity summary

Sensitivity	Description
Costs of urban transport	Costs are sensitive to future levels of demand (for example, the role of agglomeration, rates of hybrid and remote working) and how capacity is added, which means there is a wide range of potential costs which are non-linear as capacity requirements increase. For example, adding light rail, tram and rail capacity are more costly and have wider cost ranges compared to bus rapid transit. Beyond certain thresholds adding extra services on existing lines isn't sufficient to meet capacity requirements, so more costly infrastructure is needed (such as new lines, tunnelling, major station upgrades).[115]
Costs of interurban transport	Costs are sensitive to the unit costs and complexity of the interventions included in each portfolio. The interurban connectivity analysis already excludes corridors where potential improvements are likely to be unfeasible due to geography (for example, where costs may be prohibitive due to terrain). However, it makes simplifying assumptions based on benchmark costs of similar improvements (for example, an upgrade or new road) and geographical location. This means actual costs may be different at the scheme

[112] Steer (2023), Interurban Connectivity Assessment
[113] Steer (2023), Urban Transport Capacity, Demand and Cost: Research Methodology. See paragraphs 3.68 to 3.76
[114] Department for Transport (2023), National road traffic projections 2022. Report sets out how different population growth assumptions impact traffic growth
[115] Steer (2023), Urban Transport Capacity, Demand and Cost: Main Report. Tables 5.5, 5.6 and 5.7 provide infrastructure requirements for bus rapid transport, light rail and rail, and the thresholds where line extensions or new lines are required to facilitate extra services

Sensitivity	Description
	design stage, if the improvements suggested by the analysis are taken forward and developed.[116]
Benefits of urban transport	Benefits are sensitive to future levels of employment growth, which drives the economic benefits of alleviating transport capacity constraints (see **Table 2**). The potential economic benefits are in regional cities that currently underperform. But these cities also have the widest uncertainty in future demand and therefore the benefits of additional capacity. This reflects the possibility that there are lower potential agglomeration benefits from urban transport investment.[117]
Benefits of interurban transport	The economic benefits of the connectivity improvements depend on the extent to which businesses take advantage of the improved opportunities for trade. Under certain conditions, improved interurban connectivity reduces transport costs in a way that it changes the location of economic activity. Households in some places may gain from improved access to employment opportunities arising from trade specialisation and resultant clustering, but because of the 'two way roads' problem this may be at the expense of other locations losing out.[118]
Vehicle purchases	Purchasing decisions will have a significant impact on household expenditure. Decisions related to new vehicle purchases, the amount of travel and by which mode will all affect expenditure on transport. The cost of electric vehicles is expected to fall over time, reaching parity with petrol and diesel vehicles before 2030. It is possible this decline in costs will continue for some time, as new battery technology in particular reduces costs.
Operating costs and fares	Fuel costs represent the most uncertain component of operating costs, and as the vehicle fleet decarbonises this will increasingly follow the costs of electricity. The range around electricity prices used in the Assessment suggests that a fully electrified vehicle fleet could see fuel costs vary by plus or minus ten per cent.

[116] Steer (2023), Interurban Connectivity Assessment. The cost assumptions are based on benchmark costs for major road projects that are either in the pipeline or completed. The range of costs varies considerably – for example, a bypass could cost between £13.3 million and £76.4 million per km.
[117] Laird and Tveter (2022), Agglomeration under Covid. Hybrid and remote working enables some activities to be done at greater distances, which may reduce travel demand into city centres and the potential agglomeration benefits of urban transport investment. Further research is needed on the relative effects of these and what it means for the relationship between transport capacity, employment density and productivity benefits
[118] Department for Transport (2022), TAG unit A4.3 place-based analysis. Sets out the causal mechanism, based on an example where improved accessibility between two regions may benefit prosperous areas rather than the poorer areas targeted by the scheme

Digital Impact and Costings

Section 1: Assessment recommendations and outcomes

The Commission has made two digital recommendations within the Assessment.[119] The recommendations consider the best approach to support 5G deployment in the UK and the future digital needs of other infrastructure sectors.

Outcomes

The recommendations on digital infrastructure aim to support sustainable economic growth across all regions of the UK and improve the competitiveness of the UK. The recommendations should have some positive impacts on quality of life and supporting climate resilience and the transition to net zero.

The Commission has recommended that:

- the government must ensure the right conditions are in place to accelerate the market-led deployment of 5G
- the government should identify the specific telecommunications needs of the energy and water sectors, and transport sector, and ensure that infrastructure is delivered to meet these by 2030 and 2035 respectively.

The Commission's understanding of the impacts of its digital recommendations is underpinned by an Analysys Mason study into the additional costs of 5G Standalone (SA) deployment above the current level of 5G deployment (Standalone (SA) and non-Standalone (NSA)), across five potential future rollout scenarios. Modelling carried out on behalf of the Commission indicates that total 5G deployment, for the five scenarios considered, would cost between £10.5 billion and £38 billion over the next decade.[120]

Level of investment

The additional level of investment supporting these recommendations will depend on further work undertaken by government to determine the digital needs of infrastructure sectors and the best way to deliver these. The level of investment will also depend on the need for subsidised 5G deployment in the near to medium term. The Commission estimates this additional investment to be around £1 billion (2022 terms), over 10 years from 2025, to support rollout of 5G in rural areas and deliver digital infrastructure for the transport sectors (road and rail networks).[121] This is in addition to around £4 billion of existing ongoing public investment in the digital sector over the same period.

Funding and financing

5G investments are privately financed, and predominantly funded by households and businesses through telecoms billing. This is expected to continue, with the potential for some future government funding to support rural rollout and improved telecoms networks for the transport sector. Government resource spend will increase with additional funding for digital champions in local authorities.

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[119] National Infrastructure Commission (2023), second National Infrastructure Assessment

[120] To read more about the Commission's modelling scenarios, see Analysys Mason (2023), 5G wireless infrastructure deployment scenarios over the next decade

[121] This is also based on the assumption that dedicated digital infrastructure networks for the energy and water sectors would be funded by those industries rather than through direct government investment.

Section 2: Contribution towards the Commission's objectives

This section explains how the Commission's digital recommendations contribute towards its four objectives.

Support sustainable economic growth across all regions of the UK

5G has the potential to boost national economic growth. The Department for Science, Innovation and Technology (DSIT) suggest 5G could boost annual UK gross value added (GVA, a measure of economic activity) by 0.4 to 1.6 per cent in 2035.[122] This represents a cumulative productivity benefit of over £40 billion under their advanced digital technology scenario, and nearly £160 billion under their general-purpose technology scenario (a general-purpose technology — such as the railways and electricity networks — can be defined as a technology which drives a whole era of technical progress and economic growth).[123] Research undertaken by the University of Warwick for the Commission suggests 5G is unlikely to be a general purpose technology, so the top end of this range is optimistic. However, the potential scale of these impacts on GVA reflects the uncertainty over the impact of 5G.

The digital recommendations in the Assessment present an opportunity for 5G to boost productivity for business, industrial users and infrastructure firms. 5G can help firms to improve efficiencies through greater digitisation and autonomation, provide more secure and resilient networks than previous generations of wireless connectivity, and support new working practices and uses, such as augmented or virtual reality.

DSIT research estimates the largest impacts to be in London, the South East and North West.[124] Urban areas within each region are expected to benefit more strongly from 5G because mobile network operators are rolling out their networks there first.

Improve competitiveness

The impact of the recommendations on competitiveness is uncertain. The Commission has previously identified three ways infrastructure can contribute to competitiveness.[125]

Improved digital infrastructure can improve the liveability and profitability of an area, enabling people to have greater choice over where they can live and work. In rural areas improved communications infrastructure may make it easier for businesses to enable remote working or set up satellite offices, potentially attracting inwards investment to those areas.[126] New generations of digital infrastructure can enable new uses and working practices which can benefit from improvements over previous generations. For instance, the higher data capabilities of 4G allowed for access to better internet connectivity on the move, enabling the emergence of the app economy.[127]

Fixed connections, which are vital for data-intensive operations, currently seem to be more important than 5G in facilitating seamless connectivity and enhancing market access, especially for individuals. The capabilities of 5G are likely to be more beneficial to business and industrial users at present.[128] 5G could help to improve productivity for firms through increased efficiencies from digitisation and automation of processes.[129] Improving access to digital

[122] Cambridge Econometrics and Analysys Mason (2021), Realising the Benefits of 5G; Department for Science, Innovation and Technology (2023), UK Wireless Infrastructure Strategy
[123] Bresnahan, Timothy and Trajtenberg (1995), "General purpose technologies 'Engines of growth'?" Journal of Econometrics 65 (1): 83–108
[124] Cambridge Econometrics and Analysys Mason (2021), Realising the Benefits of 5G, Figure 8-12
[125] National Infrastructure Commission (2020), Improving competitiveness
[126] Ipsos (2023), Evaluation of the Superfast Broadband Programme
[127] Financial Times (2022), The search for 5G's 'killer apps'; Huffington Post (2014), The Need for Speed in the App Economy
[128] Cambridge Econometrics and Analysys Mason (2021), Realising the Benefits of 5G, p. 12
[129] Cambridge Econometrics and Analysys Mason (2021), Realising the Benefits of 5G, see Section 2

infrastructure for the transport and utilities sector can also lead to efficiency improvements in these sectors.[130] Furthermore, 5G could support new working practices and uses, such as the adoption of augmented or virtual reality in the workplace (a potential example would be to support training for engineers).[131] In addition, if use cases requiring high-capacity, low latency mobile connections emerge at scale (i.e. demand for connected and autonomous vehicles takes off), 5G mobile connections would likely become more important.[132]

While quantifying 5G's impact on regional competitiveness is challenging, evidence suggests it may enhance competitiveness in rural sectors. For instance, precision agriculture enabled by mobile coverage offers a competitive edge. Enhanced communication through increased coverage further benefits rural areas by providing greater employment opportunities.[133] However, the novelty of this technology means the benefits of 5G in this regard are unproven.

Improve quality of life

The Commission's recommendations are likely to have a net positive impact on quality of life.

The Commission defines quality of life as an assessment of an individual's overall wellbeing, and digital infrastructure and thus the recommendations in the Assessment are likely to have an impact via multiple 'domains', which in turn affect quality of life. **Table 21** summarises the most significant impacts of the recommendations on digital in the Assessment by domain.

Table 21: Summary of quality of life impacts by domain

Domain	Summary of impacts
Health	Recommendations are likely to positively affect health and wellbeing. Recommendations support and accelerate a market-based rollout of 5G. 5G healthcare uses would likely require wide area networks, so reducing deployment barriers could open up access to telemedicine in more areas.[134] Should 5G use-cases such as real-time video feeds from ambulances and drone-transported medical equipment be adopted on the back of market led rollout,[135] further subsidy for 5G deployment in potential accident hotspots (eg roadside/rural areas) which may not be reached by market led deployment alone may be justified. However these use cases are not yet widely adopted. Outside the healthcare sector, recommendations may enable better traffic management and smart cities may improve public safety, noise and air pollution.[136] Despite controversial debate, there is no evidence that 5G is harmful to health.[137]
Local and natural surroundings	Recommendations may positively impact coverage and public services, however new masts may be perceived as a negative contribution to local and natural surroundings. Some might consider that building new masts can

[130] See the Growth Across Regions chapter in the second National Infrastructure Assessment for examples of how improved digital infrastructure can enable efficiencies in other infrastructure sectors
[131] Cambridge Econometrics and Analysys Mason (2021), Realising the Benefits of 5G, p. 13; Digital Catapult report for National Grid (2022), 5G Art of the Possible, p. 29
[132] International Transport Forum (2023), Preparing Infrastructure for Automated Vehicles, pp. 42-44
[133] BDUK (2022), Benefits of Rural Mobile Coverage
[134] ABI Research (2023), Review of the 5G Ecosystem, Adoption and Industrial Use Cases, p. 76
[135] ABI Research (2023), Review of the 5G Ecosystem, Adoption and Industrial Use Cases
[136] Cambridge Econometrics and Analysys Mason (2021), Realising the Benefits of 5G; Deloitte (2018), 5G Literature Review
[137] Ofcom, What is 5G?

	negatively impact residents in the local area due to their perceived 'unsightliness'.[138] It may be possible to use telecoms to monitor pollution levels in cities or conservation areas; sewage and flood resilience. This may positively impact local and natural surroundings.
Connectivity	Improved telecoms networks positively impact connectivity. Faster and more reliable connections, particularly in rural areas, allows better access to services via the internet and improves well-being through reduced feelings of loneliness and isolation.[139]
Affordability	Improved telecoms networks have potential to reduce costs and improve efficiency across many sectors.[140] Some infrastructure providers could decide to pass on cost savings to customers,[141] however lower costs could be negated in the short-term by the increased cost of building out new telecoms networks. Mobile network operators have recently increased bills above inflation and linked this to needing to invest in new networks.[142] However UK consumers to date have shown limited willingness to pay more for 5G services,[143] and the average monthly cost of a mobile service has been falling in real terms since 2016.[144] These countervailing forces suggest bills will stay flat in real terms. It is reasonable to assume incomes will rise in real terms over time, so flat bills in real terms are likely to feel more affordable to many households.
Comfort and convenience	Telecoms can have a positive impact on comfort and convenience thanks to the use cases it can enable. Potential 5G use cases that could improve comfort and convenience include: Internet of Things and the smart grid (which requires 5G) can make energy usage easier to monitor, reducing wasted energy — and therefore bills — and reducing the time spent managing a household Faster connection for videos while travelling allows users to enjoy higher definition content. Recommendations focus on telecoms connectivity on utilities and transport sectors. There is scope for the energy sector to benefit from accurate, regular data collection which enables better supply predictions and fewer outages.[145] Water sensor networks may benefit from early fault detection causing less inconvenience to households. Smart transport management can help to reduce travel times, benefitting households.[146] CAVs may eventually improve the driver experience and reduce the need to drive.

[138] Objections to the planning approval for new masts are sometimes linked to the 'unsightliness' of masts has been raised within stakeholder discussions
[139] The Liverpool 5G project (2019), Benefits, Outcomes and Impact ; GSMA (2023), The Socio-Economic Benefits of 5G Services
[140] ABI Research (2023), Review of the 5G Ecosystem, Adoption and Industrial Use Cases
[141] Joint Radio Company (2021), Economic rationale for enabling Smart Grid functionality of the UK energy system via a Private Radio Frequency-based enhanced Operational Communications Solution
[142] Ofcom (2023), Ofcom to review inflation-linked telecoms price rises; BBC (2023), 'Mobile and Broadband price rises to be investigated'
[143] You Gov Survey (2022), Here's what Americans and Brits say about paying more for 5G. The average price premium to receive 5G mobile services has almost disappeared, as 5G is commonly offered as standard by mobile providers; Ofcom (2022), Pricing trends for communications services in the UK, p. 54
[144] Ofcom (2022), Pricing trends for communications services in the UK
[145] Analysys Mason (2020), Cost Benefit Analysis on Full 5G Deployment - UK Results, p. 13
[146] ABI Research (2023), Review of the 5G ecosystem, adoption and industrial use cases, p. 70; Cambridge Econometrics and Analysys Mason (2021), Realising the Benefits of 5G, p. 34

Employment	Recommendations support and accelerate 5G rollout, and the deployment of new telecoms networks to support infrastructure. Faster connectivity is shown to positively impact employment; however this is not 5G specific.[147] The true impact of 5G on UK employment is difficult to estimate but has the potential to be positive.[148]

Support climate resilience and the transition to net zero carbon emissions by 2050

The recommendations overall are likely to have a limited, but positive, impact on climate resilience and transition to net zero.

The impact of government accelerating the market led deployment of 5G on the objective is likely to be neutral. 5G uses more efficient data transmission methods than previous generations of mobile technology (it is estimated to be up to 90 per cent more energy efficient than 4G).[149] 5G is likely to lead to higher rates of data consumption,[150] with the possibility that mobile data demand rises to a similar level to today's demand through fixed broadband connections, which may result in higher overall energy demand. Given the decarbonisation of electricity generation, variations in energy usage due to 5G is unlikely to impact carbon emissions.

Identifying the telecommunication needs of the energy, water and transport sector may have a positive impact on this objective, as telecoms networks can play an enabling role in other sectors reducing emissions.[151] 'Smart' systems will be important for the energy sector to decarbonise.[152] Increased telecoms connectivity will be necessary to connect more remote low and medium power renewable assets to the smart grid, and there will be more demand on the network from, among other things, electric vehicle charging points or heat pumps. The energy system will need better sensors and reliable digital connectivity to ensure it can balance supply and demand of electricity at very quick intervals.[153] Real time data on road use could facilitate better traffic management and alleviate congestion, reducing emissions from road transport. Connected and self-driving vehicles could also help to reduce traffic congestion and emissions.[154] However, the impact on carbon emissions from constructing new networks should also be taken into account.

As set out in the **Section 5**, indirect carbon emissions from 5G networks, prompted by network densification and higher energy consumption through the operation of multiple frequency bands from a single base station, are expected to rise until 2030 as the network expands and fall thereafter as energy generation decarbonises. The overall indirect carbon emissions from telecoms networks are expected to be far lower than for other sectors such as transport.

[147] Oxera (2019), Impact of full fibre and 5G
[148] Accenture (2021), The Impact of 5G on the European Economy
[149] ISPreview (2020), 5G Mobile Networks up to 90% More Energy Efficient Than 4G
[150] 5G.co.uk (2023), Does 5G use more data and how much data do I need?
[151] GSMA (2019), The Enablement Effect: The impact of mobile communications technologies on carbon emissions reductions
[152] Department for Business, Energy and Industrial Strategy (2021), Smart Systems and Flexibility Plan 2021
[153] Department for Business, Energy and Industrial Strategy (2021), Smart Systems and Flexibility Plan 2021
[154] National Highways (2021), Introducing digital roads

Section 3: Impact on the Commission's fiscal remit

Total capital investment in digital over the 30-year period from 2025 would be in the order of £4 billion of committed spending. This may rise by around £1 billion under different uncertain and adaptive pathways as shown in **Table 22**.

The Commission recommends government accelerates measures to support 5G deployment. Subsidising rural rollout would require some level of funding. For a Shared Rural Network-like programme to rollout a 5G standalone network to the hardest to reach areas, the Commission estimates the total cost would be £595 million.[155] Assuming the government commits to fund 50 per cent of the costs, as happened for the 4G Shared Rural Network, there would be a government investment of just under £300 million. However, these estimates are subject to a high degree of uncertainty. At present, there is no justification for a rural subsidy based on the social value of the technology to consumers as an essential service, nor its economic impact in rural areas; these two facets of 5G would need to change for government to consider subsidising a roll-out in areas where the market is unable to deliver. Furthermore, the magnitude and scope of any subsidy would depend on the market conditions (for example 5G's commercial viability and how far a market-led roll-out would reach) at the point when a decision is made on the need for 'in-filling' in rural areas. As such, there is a high degree of uncertainty over the potential cost of any future public subsidy.

The Commission expects its recommendation on delivering telecoms for infrastructure users to lead to further spending commitments following the identification of sector infrastructure needs, either to fund the infrastructure directly or to incentivise mobile network operator (MNO) build. Government investment may be needed to subsidise MNO rollout or directly fund dedicated networks i.e., transport. Alternatively, coverage obligations could be placed on networks during future spectrum auctions or in return for reduced spectrum annual licence fees, which will see lower returns to the Treasury. The utilities (energy and water) sector would be likely to privately finance their networks to suit their needs, however road and rail networks may need to be funded directly by Government. Commission analysis suggests that capital expenditure for a bespoke network for transport costs £720 million between 2022 and 2030. [156] Given the high levels of uncertainty about what road and rail networks would be needed, this investment estimate sits within the Commission's 'uncertainty and adaptive pathways' spend line in the fiscal remit.

Table 23 shows an indicative forward projection of today's government capital spending for digital spend, and additional government capital financing supporting the Commission's digital recommendations.

[155] The Shared Rural Network (SRN) will deliver reliable mobile broadband (4G) combined coverage to 95 per cent of the UK, boosting coverage in areas with limited existing coverage. It will provide guaranteed coverage to 280,000 premises and 16,000km of roads, with the biggest coverage improvements in rural parts of Scotland, Northern Ireland and Wales. Source: SRN, Forecast coverage improvements

[156] Analysys Mason (2023), 5G wireless infrastructure deployment scenarios over the next decade. This report prepared for the Commission presents a comparable present value cost of £873 million. With operational expenditure, the present value figure for bespoke transport networks totals £1.5 billion

Table 22: Fiscal remit impact, average annual expenditure (£ million 2022 prices, 2025-2054)

Source of costs	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Total digital recommendations	870	100	10	0	0	0
Project Gigabit	750	0	0	0	0	0
Shared rural network and R&D	30	0	0	0	0	0
Uncertainty and Adaptive pathway: Digital recommendations	90	100	10	0	0	0

Section 4: Impact on the Commission's economic remit

This section details how the digital recommendations in the Assessment will affect household and business bills. Based on historical data on investment and bills, 'inflation+x%' pricing formulas, recent regulatory decisions and consumer behaviour, alongside evidence of declining price per GB data, the Commission assumes bills will not rise as a result of 5G investment.[157]

The recommendations suggest some additional spending to be captured in the economic remit.

Costs to households and business

The Commission has assumed that future investment in bespoke telecoms networks for utilities is privately financed by energy and water companies. Modelling suggests bespoke networks would cost around £815 million per network (£393 million capital expenditure and £422 million operational expenditure).

Table 23.a shows that average spending by households on digital infrastructure remains constant between 2025 to 2054. These costs include telecoms subscriptions and household capital expenditure on telecoms such as mobile phones and broadband routers.

Table 23.b shows the aggregate spending by households and business on digital infrastructure remains relatively flat over the period from 2022 to 2055. This table sums existing expenditure and additional expenditure required as a result of recommendations.

Table 23.a: Economic remit impact, average digital expenditure per household (£ per household 2022 prices, 2025-2054)

Category	2022 comparator	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Households	1,140	1,040-1,250	1,040-1,250	1,040-1,250	1,040-1,250	1,040-1,250	1,040-1,250
Broadband bill	500	450-550	450-550	450-550	450-550	450-550	450-550
Mobile bill	440	400-490	400-490	400-490	400-490	400-490	400-490
Capital expenditure	200	190-210	190-210	190-210	190-210	190-210	190-210

Table 23.b: Economic remit impact, average annual expenditure costs to households and businesses (£ million 2022 prices, 2025-2054)

Category	2022 comparator	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Households	27,200	25,600-30,600	26,300-31,500	27,000-32,400	27,400-32,900	27,600-33,100	27,800-33,300
Fixed and mobile bills	22,500	20,900-25,600	21,600-26,400	22,100-27,100	22,500-27,500	22,600-27,700	22,700-27,800
Digital capex	4,700	4,600 - 5,000	4,800-5,200	4,900-5,300	5,000-5,400	5,000-5,400	5,000-5,500
Business and industry bills	4,100	3,800-4,600	3,400-4,600	3,000-4,600	2,700-4,600	2,400-4,600	2,200 – 4,600

[157] Ofcom (2022), Pricing trends for communications services in the UK

Costs to the public sector

The Commission recommends funding for 'Digital Champions' in local authorities to support 5G deployment. Additional funding of a little over £10 million per annum would be required in the form of government resource spending, based on funding of up to £40,000 per council serving as a local planning authority, allocated to all such councils without an existing digital champion (69 per cent).[158] The cost of this is shown in **Table 23.c.**

Table 23.c: Economic remit impact, average annual expenditure by the public sector (£ million 2022 prices, 2025-2054)

Category	2022 comparator	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Government resource spend on policy	0	10	0	0	0	0	0

[158] TechUK (2022), Building Mobile Britain: The Case for Local Authority Digital Champions

Section 5: Environmental impacts

The Commission measures the environmental impact of its recommendations across three environmental domains: air pollution, biodiversity, and water quality. These are three of the themes in the government's 25 year environment plan relevant to the Commission's recommendations. The impact of the digital recommendations on these domains is summarised in **Table 24.**

The Commission also measures the carbon impact of its recommendations. This includes embodied carbon in the construction of infrastructure and operational carbon emissions.

Table 24: Environmental assessment of the digital recommendations

Environmental impact	Contribution to net gain
Air pollution	5G masts and the wider network will have no adverse impact on air quality. Further telecoms networks can support the collection of more data from air quality sensors. This data can be used to track air quality levels over time and identify trends which may support better management of air pollutants in future. [159]
Water quality	5G masts and the wider network will have no adverse impact on UK waters. Increased digitisation of the water network could include the collection of more data from water quality sensors. This data can be used to track water quality levels over time and identify trends. [160]
Biodiversity	The natural capital impact of 5G networks in biodiverse-rich areas is minimal. According to Analysys Mason modelling, there are approximately 0.06 macrosites per square kilometre in rural areas. [161] This footprint is extremely unlikely to result in negative impacts at the habitat scale. The evidence surrounding the impact of 5G technology on biodiversity is limited. There may be some possibility of negative impacts of 5G technology on biodiversity, but most studies are inconclusive.[162]

Carbon impacts

5G networks represent less than one per cent of overall UK carbon emissions.[163] By 2030 UK 5G networks are forecasted to generate between 0.8 and 1.2 $MtCO_2$ of annual indirect carbon emissions, prompted by 5G network densification.[164] Aggregate energy consumption of UK cellular networks will increase with the densification and upgrading of micro- and macro-cells. Research shows energy consumption of 5G more than tripling in the next 10 years, from 1.8TWh in 2021 to 8.4TWh in 2030. This will represent approximately two per cent of total UK electricity generation.[165] However, energy emissions are set to decline as energy use decarbonises.

[159] 5G.co.uk (2018), MegaSense project uses 5G to monitor and improve air quality
[160] Ericsson (2022), Optimizing smart water solutions with 5G, IoT and BSS
[161] Analysys Mason (2023), 5G wireless infrastructure deployment scenarios over the next decade
[162] European Parliament (2021), Environmental impacts of 5G
[163] Department for Business, Energy and Industrial Strategy (2022), 2021 UK greenhouse gas emissions, provisional figures. UK greenhouse gas emissions rose to 341.5 $MtCO_2e$ in 2021. The upper estimate by Cheng et al. of 1.2 $MtCO_2e$ is approximately 0.35 per cent of this
[164] Cheng et al. (2022), 5G network deployment and the associated energy consumption in the UK: A complex systems' exploration p. 17. Note that this may not be aligned to Commission recommendations on decarbonising the electricity sector, although it is consistent with the UK electricity mix projected by Carbon Brief analysis of new government projections.
[165] Ofcom (2012), Assessment of future mobile competition and proposals for the award of 800 MHz and 2.6 GHz spectrum and related issues, Annexes 7-13. The total electricity generation in 2030 in the UK is estimated to 393 TWh

Section 6: Distributional impacts

This section assesses the distributional impacts of the Commission's digital recommendations across a set of dimensions, based on a set of assumptions, across different income and expenditure groups and across consumers in different regions.

5G deployment is not expected to significantly increase mobile telecoms bills without a major new use case or shift in business model for MNOs. Overall, the Commission's digital recommendations are unlikely to alter the existing spending patterns across income groups, geography and protected characteristics. **Table 25** therefore focusses on the background patterns of spending on digital services by different household groups.

Table 25: Distributional impact summary

Dimension	Description
Income groups	Commission analysis on distributional impacts suggests the proportion of expenditure on digital falls as income increases. The highest income decile spends about half that of lower income deciles, as a proportion of their total expenditure. Social tariffs are available to the lowest income households.
Vulnerable and protected groups	**Age** — Older adults are more likely than other age groups to have lower digital literacy, and therefore have less access to digital services.[166] They may also be excluded from some parts of the workforce.[167] Older adults may in the long-term benefit from any improvements in 5G availability stemming from the recommendations (particularly if this leads to support for innovations such as remote healthcare or voice activated internet services, which they may be disproportionately reliant on relative to the general population). However, at present these use cases have not been widely adopted. **Disability** — More than half of adults who do not use the internet are disabled, much higher than the proportion of disabled adults in the UK population as a whole, which in 2021-22 was estimated to be 24 per cent.[168] Individuals with disabilities may have lower digital literacy and find it harder to use digital assets.[169] Conversely, digital infrastructure may enable use cases to improve quality of life for those with disabilities, for example having digital consultations with GPs rather than in person visits, remote working, text-to-voice software. **Race** — Government data suggests some disparities in internet usage among different ethnicities.[170] By widening access to mobile broadband, 5G technology may increase the uptake of high-speed internet connections amongst ethnic minorities, who tend to be overrepresented towards the bottom of the income distribution. There is some evidence of this happening in other countries such as the USA. [171] Mobile network operators also provide social tariffs to widen access to those with the least ability to pay for wireless services. However, there is some evidence from other countries that certain digital technologies (such as Artificial Intelligence and facial recognition technology) may

[166] Ofcom (2006), Media Literacy Audit: Report on media literacy amongst older people
[167] Office for National Statistics (2019), Exploring the UK's digital divide
[168] Office for National Statistics (2019), Exploring the UK's digital divide; Family resources survey 2021-22 (2023)
[169]Ofcom (2022), Pricing trends for communications services in the UK
[170] Office for National Statistics (2019), Exploring the UK's digital divide
[171] Brookings (2019), Enabling opportunities: 5G, the internet of things, and communities of color

	entrench racial inequalities.[172] 5G may increase these trends by increasing the availability and functionality of certain digital technologies, such as those used in surveillance, though this would be a secondary impact of deploying these networks. It is too early to say whether 5G will magnify these trends in a UK context. There is no evidence to suggest disparities in access to 5G on the basis of sex, gender reassignment, marital status, pregnancy and maternity leave, religion or belief, or sexual orientation.
Geographical	The largest telecoms firms are nationwide and compete across the country, and do not tend to offer regionally differentiated pricing. Rural areas typically experience inferior mobile coverage to urban areas.[173] DSIT analysis suggests a weaker investment case for 5G rollout in rural areas, due to the steep increase in the cost of rural 5G deployment.[174] This suggests rural areas may not experience the same benefits of 5G as those in urban and suburban areas, or these benefits will be delayed. Given the overlap between rural areas and older people,[175] digital exclusion may further present itself as an issue. The Wireless Infrastructure Strategy goes some way to addressing the gap in rural 5G coverage. It adopts an ambition to deliver nationwide standalone 5G coverage to all populated areas by 2030, calls for better data reporting and includes a ten point plan for improving rural connectivity.[176] The recommendation to accelerate the deployment of 5G supports this. It is not yet clear whether the government needs to go further through subsidisation of rural rollout, as they have with the Shared Rural Network.

[172] United Nations (2020), Emerging digital technologies entrench racial inequality, UN expert warns
[173] Ofcom (2022), Connected Nations 2022: UK report
[174] Analysys Mason and Oxera (2022), Ensuring future wireless connectivity needs are met - final report for DCMS
[175] Department for Environment, Food and Rural Affairs (2021), Statistical Digest of Rural England
[176] Department for Science, Innovation and Technology (2023), UK Wireless Infrastructure Strategy

Section 7: Uncertainty

This section presents how robust the Commission's recommendations are to different possible future states of the world based on a set of drivers, and to changes in assumptions. It assesses the degree of confidence in the fiscal and economic remit estimates, and other impacts outlined above, and the reasons for this judgement. These are set out under three risk classifications, as set out in the Commission's managing uncertainty framework.[177]

Table 26 describes some key areas of uncertainty which may influence the impact of the recommendations and 5G deployment.

Table 26: Uncertainty summary

Driver	Classification	Description
Economic growth	Robust	Recommendations for government to assess the case for further support to 5G are inherently robust to future economic growth. Higher or lower economic growth may impact the investment case for 5G deployment. Lower growth may make the market based approach less effective and require more intervention from government to roll out to less populated areas. Alternatively, market consolidation may strengthen the case for private investment.
Climate change	Robust	Recommendations are robust to a range of possible increases in global average surface temperature. Demand for 5G deployment may increase if there is some indication that 5G is an enabler of climate change mitigation, or allows better monitoring of heat-stressed assets. This would make identifying sectoral needs for future telecommunications more important.
Technology and behaviour change	Robust	Recommendations are robust to a range of technology scenarios. The emergence of new use cases, or a mass increase in demand, might require more extensive rural rollout, or spectrum or technology to be available faster than currently planned. This could require recommendations to go further, though it is more likely to increase the commercial viability of 5G. These recommendations are robust to the emergence of new technologies. Should a new technology replace 5G, such as satellite, this should be considered as government identifies the specific telecommunication needs of energy, water and transport infrastructure. Recommendations are robust to a range of behaviour scenarios. A decline in trust in 5G due to cyber-attacks, public health misinformation or poor governance and regulation may require recommendations to go further.
Population and demography	Robust	Recommendations are robust to population and demography changes. Higher population growth may

[177] National Infrastructure Commission (2022), Managing uncertainty in the second National Infrastructure Assessment

Driver	Classification	Description
		strengthen the investment case for market-based rollout, supporting recommendations.

Table 27: Sensitivity summary

Sensitivity	Description
Consumer behaviour	Consumer behaviour may cause some variation in bill projections presented in the economic remit. Commission analysis assumes rates of contract switching stay fairly stable. More switching to cheaper contracts may cause bills to drop. Less switching may see out-of-contract customers paying higher premiums for longer rather than switching to relatively cheaper contracts, or 'inflation + X%' pricing formulas driving bills upwards. These two forces are assumed to balance out, projecting broadly flat bills, but variation in the above balance of contracts is captured in the ranges of bill projections.
Mix of infrastructure deployed	There are a range of scenarios which estimate the cost of different digital infrastructure deployed, including macro cells, small cells, mmWave, spectrum, 5G standalone architecture.[178] These feature a combination of infrastructure deployments to meet different levels of demand for 5G. Rollout of 5G may differ from the Commission's modelled scenarios. Therefore, costs may change, but should remain in the costs captured by modelled scenarios, ranging from £10.5 billion to £35 billion. Relative to Scenario 3, Scenario 4 deploys 3.5GHz spectrum to rural areas and mmWave much more extensively, alongside a further 6287 macro sites and 53 009 new outdoor small cells are built per hypothetical MNO (increasing by more than 2x and 12x respectively). This amounts to almost an £18 billion rise in costs. Variation in costs may cause some variation in bill projections, which are reflected in the ranges presented in **Tables 22a** and **22b.**
Unit costs of active, passive, backhaul and core infrastructure	**Unit capital costs** Unit capital cost assumptions reflected in the modelling are based on Analysys Mason estimates of typical European MNO equipment cost, and do not reflect individual vendor costs. Most assets costed by Analysys Mason are relatively well established and therefore present a good central estimate. Costs may be subject to materials price inflation, innovations that reduce price or by pace of rollout both nationally and internationally. More novel network costs include 5G standalone core costs. Both public and private core costs are informed by Analysys Mason discussions with industry players. These costs are more uncertain, as demand, complexity and innovation may change costs in future. **Unit operating costs** Unit operating costs include labour and construction, hardware support and maintenance. Assumptions of these costs reflected in the modelling are based on Analysys Mason estimates of typical European MNO equipment cost, and do not reflect individual vendor costs. Costs may be

[178] Analysys Mason (2023), 5G wireless infrastructure deployment scenarios over the next decade

	subject to materials price inflation, innovations that reduce price or by pace of rollout both nationally and internationally, as detailed above.
Growth of private networks	Private networks may become more or less prevalent than is assumed in Commission analysis. This will affect the need for public 5G rollout, and therefore the costs of rollout. The modelled scenarios capture a variety of private network deployment, delivered via a public slice or through dedicated infrastructure. To demonstrate the scale of this, Scenario 2 incorporates 5938 additional private and public sector localised private networks. This presents an additional cost of £3.5 billion relative to Scenario 1. Similarly, Scenario 5 exhibits an additional cost of £5 billion relative to Scenario 4. This captures the cost of dedicated transport corridor and utility networks and an additional 4925 localised private networks.[179]
Cost of capital	The weighted average cost of capital is taken from Ofcom's most recent charge control decisions and adjusted marginally up and down to reflect a plausible range.
Household and business bills	The overall range around household and business bills in the economic remit reflects the Commission's view of reasonable combinations of the above sensitivities and is set at plus or minus ten per cent around the central estimates.

[179]Analysys Mason (2023), 5G wireless infrastructure deployment scenarios over the next decade

Waste Impact and Costing

Section 1: Assessment recommendations and outcomes

The Commission has made two recommendations on waste and the circular economy within the Assessment.[180]

Outcomes

The Commission's recommendations signal a significant shift away from energy from waste, particularly unabated energy from waste, in favour of recycling. This shift should not only prioritise environmental sustainability but also offer better value for taxpayers, as recycling proves to be a more cost effective treatment option than incineration.

The Commission's recommendation on data gathering on commercial and industrial waste will inform associated policies aimed at improving recycling practices and increasing landfill taxes, thereby ensuring that waste moves up the hierarchy.

These recommendations will steer England's waste sector towards decarbonisation and a more circular economy. This transformation will be marked by increased recycling rates and reduced environmental impacts, aligning the sector with its goal of achieving net zero emissions by 2050.

The outcomes of the Commission's recommendations are informed by a Ricardo study into the role of the waste sector in moving towards a more circular economy. This study involved:

- modelling the current performance of the waste sector in terms of capacity, cost and environmental impact
- developing and modelling the least cost infrastructure pathway for the waste sector to meet the Sixth Carbon Budget by 2035 and net zero by 2050
- identifying waste streams with the greatest negative environmental impact of extraction and processing and potential for circularity
- modelling the capacity and mix of infrastructure required to deliver different circularity targets for each waste stream.

Level of investment

The Commission's recommendations entail an investment of £24 billion (in 2022 terms) over the next 30 years.[181] This substantial investment is largely made up of an expansion in recycling capacity, brought about by the introduction of policies such as consistent recycling collections, separate food and garden waste collections, extended producer responsibility, and a deposit return scheme. The investment represents a strategic shift in resources, diverting them away from unabated energy from waste and towards recycling. The anticipated total investment aligns with the capital cost projections developed by Ricardo Energy & Environment as part of their net zero pathways modelling.

Funding and financing

Investment in waste infrastructure is predominantly financed by the private sector. Companies will either raise finance through their balance sheets or rely on bank debt.[182] Other investment in the sector is either funded directly by local authorities or, historically, financed indirectly

[180] National Infrastructure Commission (2023), second National Infrastructure Assessment
[181] Ricardo Energy & Environment (2023), Waste Infrastructure Technology Mix Report, pp. 6-7. High level estimate of investment required to meet net zero. Midpoints taken from high level estimates
[182] All-Party Parliamentary Sustainable Resource Group (2013), Rubbish to Resource - Financing New Waste Infrastructure

through private finance initiative contracts with the private sector. These are long-term contractual arrangements in which the private sector provides the upfront capital investment to build new infrastructure, with the public sector paying this back over time.

Funding of most waste infrastructure investments is largely through gate fees. A smaller portion is funded through revenue from packaging recovery notes, or through selling energy and other materials from treatment processes. These costs are covered by the Commission's economic remit.

Section 2: Contribution towards the Commission's objectives

This section explains how the Commission's waste recommendations contribute towards its four objectives.

Support sustainable economic growth across all regions of the UK

The effects of the required expansion in recycling capacity to accommodate the waste collection reforms and materials regulations and divert waste from unabated energy from waste to material recycling facilities on supporting sustainable growth are uncertain and depend on the balance between the additional short-run cost of recycling set against the longer term value of keeping more resources in productive use.

WRAP's recent gate fees report shows recycling gate fees are higher than landfill gate fees once the landfill tax is removed.[183] This would suggest increased recycling may reduce firm-level productivity. However, disposal to landfill or incineration removes the possibility of resources finding future productive uses, in effect reducing the useful capital available to generate economic outputs. Coordination failures in the collection and disposal system may prevent the waste industry from benefitting from economies of scale that could ultimately reduce the costs and increase the value of recycled materials. It is currently unclear which is the larger economic effect between the well understood cost to business of waste management and the potential to generate future value from a reformed system. As such, the contribution of the Commission's recommendations for the waste sector to sustainable economic growth is ambiguous.

Improve competitiveness

Commission analysis estimates a ban on unabated energy from waste should help to increase demand for recycling infrastructure by avoiding locking into long term energy from waste without carbon capture assets. Paired with the implementation of the waste collection reforms and materials regulations, which will ensure that separately collected materials are directed towards the appropriate treatment routes, this should ensure regular feedstocks into recycling. This could improve investor confidence and potentially the competitiveness of this part of the market. Recycling facilities may also be able to operate more competitively against raw material manufacturers, due to the consistent feedstocks.

Improve quality of life

Overall, the recommendations on waste in the Assessment positively contribute to the Commission's quality of life objective.

Table 28: Summary of quality of life impacts by domain

Domain	Summary of impacts
Health	Positive physical health impacts from reduced air pollution from unabated energy from waste and landfill.
Local and natural surroundings	Improvements in the natural environment through overall reduction in the number of energy from waste facilities and landfill capacity. Reducing the number of facilities will reduce air pollution. Increased recycling leads to less resource extraction, largely felt in countries outside the UK.
Connectivity	No direct contribution to physical or digital connectivity.
Affordability	The Commission's recommendations lead to an increase in the total costs of the waste system over the next decade relative to today. However,

[183] WRAP (2023), Gate fees report 2022/23

	looking over the next 30 years households can expect their costs (as paid through council tax) to be broadly similar to today. Any future growth in household incomes should lead households to put a smaller share of total spending towards waste services in future, modestly improving affordability.
Comfort and convenience	Simpler recycling and other reforms will simplify the recycling process for households and businesses. Furthermore, the introduction of consistent collections across local authorities will ensure clear and uniform messaging about waste separation, making it easier for everyone to participate in recycling efforts.
Employment	The reforms necessitate an expansion in recycling capacity, diverting waste from unabated energy from waste to material recovery facilities. As recycling requires more labour than energy from waste and landfill due to the need for additional sorting and processing, this diversion may result in an increase in jobs in the sector.[184]

Support climate resilience and the transition to net zero carbon emissions by 2050

Overall, the recommendations positively contribute to climate resilience and the transition to net zero carbon emissions by 2050.

Commission analysis suggests reducing waste sent to landfill and unabated energy from waste can contribute to achieving net zero. Larger quantities of waste will need to be recycled.[185] Recommendations should improve the quantity and quality of recycling, while reducing unabated energy from waste capacity. This should encourage both demand and investment in recycling facilities and abated energy from waste, contributing to the delivery of net zero.

The Commission advises government to implement its reforms without delay. These reforms should improve the quality and the quantity of waste collected for recycling and should go some way to reducing emissions from the waste sector, as landfill and energy from wase use are reduced. The impact of these reforms is discussed further in **Section 5**.

[184] Zero Waste Europe (2021), New study shows that including incineration under the EU ETS is a path to generate climate benefits and employment
[185] Ricardo Energy & Environment (2023), Waste Infrastructure Technology Mix Report

Section 3: Impact on the Commission's fiscal remit

The fiscal remit captures public capital investment. Current investment in the waste sector by local authorities in England is £530 million. This investment captures local authority waste infrastructure such as bins and collection vehicles.

The fiscal cost of recommendations on the waste sector are presented in **Table 29**. The recommendations are not expected to require any increase in public capital investment, so current local authority investment is rolled forward and assumed to be flat in real terms.

Recommendations will also require private investment from the waste sector, and government operational expenditure. These are detailed in the economic remit in **Section 4**.

Table 29: Fiscal remit impact, average annual expenditure (£ million 2022 prices, 2025-2054)

Source of costs	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Total waste recommendations	500	500	500	500	500	500
Local authority waste investment	500	500	500	500	500	500

Section 4: Impact on the Commission's economic remit

The waste recommendations in the Assessment will affect the economic remit through costs to local authorities, passed through to households through council tax and the costs of waste disposal services for businesses. Under the Commission's recommendations, total costs would rise in the medium term, and then decline after 2035, though remaining higher than current levels.

The Commission recommends government to implement its waste collection reforms without delay. The latest available cost data based on government proposals is linked to Defra's impact assessment on its collection and packaging reforms. Defra's impact assessment suggests costs increase in three policy areas, summarised to a present value of at £46.5 billion in 2022 prices.

Table 30: Costs outlined in Defra's collection and packaging reforms borne by businesses and local authorities (£ million, 2022-2035)

	Extended producer responsibility	Deposit return scheme	Consistent collections	Total (2022-2035)
2019 prices	16,900	6,800	6,800	**30,600**
2022 prices	25,500	10,100	10,900	**46,500**

Financial support to local authorities, public organisations and businesses for transitional costs is estimated to require £11 million funding per year.[186]

The Commission also recommends research into the composition and waste treatment destinations for commercial and industrial waste in England. The costs of research will vary depending on the scope and duration of the project. Comparable Defra programmes have cost £1.7 to £2 million per surveyed year.[187]

The costs of expanding the single use plastics ban have not been explored as part of Commission analysis, as the Commission is primarily reiterating its recommendation from the first National Infrastructure Assessment. A potential comparable scheme might be Defra's recent impact assessment of a ban on the supply of single use plastic plates and cutlery in England which suggests familiarisation, enforcement, material, and fuel costs; landfill disposal emissions and fuel emissions costs; and additional waste management costs. These sum to a 2020 present value of over £90 million (approximately £130 million in undiscounted, 2022 prices).[188]

The Commission also recommends government should ban future energy from waste capacity that does not include carbon capture and storage and increase the landfill tax to ensure it remains more expensive than energy from waste. Banning new unabated energy from waste will force local authorities and businesses to use alternative waste treatment methods instead, such as recycling or abated energy from waste.

From 2028, energy from waste will be part of the emissions trading scheme. This will cause energy from waste gate fees to rise, subject to contract, as a cost is attached to greenhouse gas emissions. From 2030, the additional investment of installing carbon capture and storage technology at energy from waste plants and their consequent ability to generate revenue from emissions trading will be reflected by a change in gate fees. This is shown in **Table 31**.

[186] Department for Environment, Food and Rural Affairs (2021), The Collection and Packaging Reforms – A summary of the impacts
[187] UK Government Contracts Finder (2022), Programme of work on mixed waste composition
[188] Department for Environment, Food and Rural Affairs (2021), Plates and Cutlery Impact Assessment

Table 31: Estimated gate fees by method (£ 2022 prices)

Technology (all include transport)	2030
Landfill (excluding landfill tax)	28
Material recovery facilities	80
Abated energy from waste	130
Unabated energy from waste	170

Note: Energy from waste gate fees under the emissions trading scheme will vary over time depending on carbon prices. This table provides a snapshot of 2030 gate fee estimates in 2022 real prices. More detail on the method to estimate the uplift in gate fees can be found in Ricardo's report for the Commission.[189]

Costs of recommendations to businesses, local authorities and government

The Commission estimates total costs to local authorities and businesses will likely rise over time, although where local authority costs are shared across a larger population than today, cost per household will be broadly similar to today. This increase in costs is due to the implementation of collection and packaging reforms, the introduction of energy from waste into the emissions trading scheme and the banning of new unabated energy from waste.

Table 32 shows the highest costs to business, industry and government arise in the early 2030s, as new unabated energy from waste is phased out and either replaced with more costly abated energy from waste, or existing unabated plants are subject to the emissions trading scheme. Costs then fall as local authorities and businesses switch to sending waste to relatively cheaper recycling centres. Clear signalling ahead of time has the potential to reduce the peak in costs, with local authorities and businesses switching to cheaper recycling streams before energy from waste costs rise.

Table 32: Economic remit impact, average annual waste expenditure by households, businesses and government (£ million 2022 prices, 2025-2054)

Category	2022 comparator	2025-29	2030-34	2035-39	2040-44	2045-49	2050-54
Total waste expenditure	11,000	14,800-16,800	15,100-17,100	11,700-13,700	11,600-13,700	12,000-14,200	12,400-14,700
Business and industry	7,600	10,600-12,300	10,900-12,700	8,000-9,900	8,300-10,300	8,700-10,700	9,100-11,200
Government resource spend	3,400	4,200-4,500	4,200-4,300	3,700-3,800	3,300-3,500	3,300-3,500	3,300-3,500

[189] Ricardo Energy & Environment (2023), Waste Infrastructure Technology Mix Report

Section 5: Environmental impacts

The Commission measures the environmental impact of its recommendations across three environmental domains: air pollution, biodiversity and water quality. These are three of the themes in the government's 25 year environment plan relevant to the Commission's recommendations.[190] The impact of the waste recommendations on these domains is summarised in **Table 33**.

In addition, higher recycling rates have the potential to reduce raw materials extraction, and the associated environmental damage, elsewhere in the world. Below the table, a section on non-domestic impacts takes a global perspective on the environmental impacts of the Commission's recommendations.

The Commission also measures the carbon impact of its recommendations. This includes embodied carbon in the manufacturing and construction of infrastructure as well as carbon emissions from the operation of waste infrastructure.

Table 33: Environmental assessment of the waste and circular economy recommendations

Environmental impact	Contribution to net gain
Air pollution	The Commission's recommendations on energy from waste are expected to contribute to a reduction in the sector's contribution to air pollution. Although the waste sector's impact on air quality is marginal compared to larger industries, energy from waste facilities emit nitrogen oxides and particulate matter emissions which contribute to air pollution. A ban on unabated energy from waste facilities and a reduction in the overall capacity of energy from waste is expected to lead to a decrease in nitrogen oxides and particulate matter emissions from the waste sector.
Water quality	The Commission's waste recommendations are likely to limit additional impacts on water quality by reducing the proportion of future waste arisings that go to landfill. Stringent regulations are already in place to ensure that potential water quality impacts from landfill sites are minimised. Landfill operators are required to design and build their sites to protect the environment, which includes managing the effectiveness of the leachate collection system and of any groundwater control systems. If the Commission's recommendations are followed and the collection reforms and materials regulations are implemented, fewer materials will enter landfill sites. This reduction in landfill capacity, largely driven by diverting more residual waste to recycling, will further reduce any existing risk of groundwater contamination.
Biodiversity	There are potential negative impacts on biodiversity given the associated increase in land take from an anticipated increase in the number of recycling and abated energy from waste facilities. Commission analysis estimates that five fewer average sized energy from waste facilities (with an average capacity of 350,000 tonnes) will be needed by 2035 compared to today, but 55 additional material recovery facilities

[190] Department for Environment, Food and Rural Affairs (2023), 25 Year Environment Plan

	(with an average capacity of 65,000 tonnes) will be required. Additionally, around six energy from waste facilities will need to be upgraded to include carbon capture and storage equipment, which requires additional land take of approximately one third of the footprint of existing energy from waste facilities. The introduction of carbon capture and storage technology, and rapid rise in required material recovery facilities plants, will likely result in a net increase in land take for the waste sector, which could negatively impact natural habitats and wildlife populations if greenfield sites are used. Use of existing industrial sites and application of biodiversity net gain across local authorities should help to avoid or mitigate this. Commission analysis estimates there could be a need for avoidance or mitigation activities worth up to around 2,600 biodiversity units.[191]

Non-domestic environmental impacts

The Commission's recommendations would promote a more circular economy, which will ensure that a greater quantity of materials remain in productive use within the economy for longer.

Recycled materials can be expected to replace some new raw materials, thereby minimising the environmental impacts associated with their extraction and processing. These impacts can include significant negative effects on air quality, water quality and biodiversity. Analysis for the Commission by Ricardo has attempted to quantify the potential reductions in pollution associated with lower resource extraction and serves to demonstrate that it may be significant, although the nature of this analysis on a global scale means the results are highly uncertain.[192]

Carbon impacts

The Commission recommends the implementation of collection reforms, the packaging extended producer responsibility scheme and the deposit return scheme. Defra's impact assessment[193] on these reforms suggests total carbon savings over the 2022 to 2035 appraisal period reach over 60 megatonnes broken down by waste stream in **Table 34**.

Table 34: Total carbon emission savings ($MtCO_2e$, 2022-2035)

Extended producer responsibility	All-in-Deposit return scheme	Consistent collections	Total (2022-2035)
4.4	3.4	54	62

The Commission recommends expanding the single use plastics ban. This is expected to reduce carbon emissions. The precise impact of a single use plastics ban will depend on the scope of the ban. Defra estimates its single use plastic ban for plates and cutlery to result in a 0.015 change in greenhouse gas emissions.[194]

The Commission advises banning future unabated energy from waste. A reduction from 17 million tonnes of unabated energy from waste in 2022 to four million tonnes in 2050 would result in a saving of five $MtCO_2e$ over the 28 years. The recommended ban should further reduce total

[191] A biodiversity unit is a habitat based approach used to assess an area's value to wildlife. Department for Environment, Food & Rural Affairs (2021), Biodiversity metric: calculate the biodiversity net gain of a project or development
[192] Ricardo Energy & Environment (2023), Waste Infrastructure Technology Mix Report. Data limitations meant exports and waste treated outside the UK were not included in this analysis
[193] Department for Environment, Food and Rural Affairs (2021), The Collection and Packaging Reforms – A summary of the impacts. Table 2
[194] Department for Environment, Food and Rural Affairs (2021), Plates and Cutlery Impact Assessment

unabated energy from waste tonnages and therefore increase carbon savings. This is in addition to the carbon savings expected in Defra's recycling reforms outlined in **Table 34**.

Section 6: Distributional impacts

The Commission has evaluated the impacts of recommendations in the waste sector, based on a set of assumptions, across different dimensions — income groups, geography, and protected characteristics — focusing on where there are disproportionate effects on particular groups. These are summarised in **Table 35.**

Table 35: Distributional impact summary

Dimension	Description
Income groups	The impact of the Commission's recommendations on different income groups are mixed. The simpler recycling reforms will deliver overall savings to households, as the Commission's analysis indicates that sending waste to material recycling facilities is the more affordable option for waste treatment. Additionally, the reforms aim to shift the cost of managing packaging waste from local authorities and taxpayers to producers. Any upfront investment required for building new recycling capacity to treat household waste will ultimately be reflected in household council taxes. Government resource spending on waste is expected to be broadly flat on a per household basis, suggesting waste elements of council tax bills will be too. Council tax is thought to place a disproportionate burden on low income households and the Commission's recommendations are unlikely to change this.[195] Additionally, while producers will directly bear the costs of waste management under extended producer responsibilities, they can be expected to pass these on to their customers. The impact this will have on different income groups is unclear.[196]
Vulnerable and protected groups	There are distinct groups and individuals within the population who may encounter difficulties regarding the proposed recycling reforms. These groups and individuals will require support to ensure their effective engagement with the envisioned recycling system. To address these challenges, several mitigations have already been proposed and are currently in use. Implementing the Commission's recommendations on individual local authority targets will also ensure differences in housing and population mix will be accounted for. With the right support, these groups will be able to participate in the kind of recycling system the government is advocating for. **Older** individuals may require targeted assistance to meet collection requirements. This assistance will include putting out additional bins for food and garden waste which could be demanding due to mobility issues or underlying health conditions.

[195] Institute for Fiscal Studies (2020), Revaluation and reform: bringing council tax in England into the 21st century
[196] Department for Environment, Food and Rural Affairs (2021), The Collection and Packaging Reforms – A summary of the impacts

Dimension	Description
	Similarly, some individuals with **physical or mental disabilities** will face challenges in complying with collection requirements, particularly in terms of sorting separating food and garden waste for collection and may also require targeted assistance from local authorities. There is no evidence to suggest the Commission's waste recommendations will pose different impacts on the basis of race, sex, gender reassignment, marital status, pregnancy and maternity leave, religion or belief, or sexual orientation.
Geographical	The simpler recycling reforms will have direct impacts on minimising differences in household waste management services across different regions. Local authorities will be mandated to collect a consistent range of dry materials from households across all areas in England, including a weekly separate food waste collection, and garden waste collection.[197] This improved material segregation and consistent approach to waste disposal will simplify the recycling process for households and will reduce geographic disparities in service delivery.

[197] Department for Environment, Food and Rural Affairs (2021), The Collection and Packaging Reforms – A summary of the impacts

Section 7: Uncertainty

This section presents how robust the Commission's recommendations are to different possible future states of the world based on a set of drivers and to changes in assumptions. It assesses the degree of confidence in the fiscal and economic remit estimates, and other impacts outlined above, and the reasons for this judgement.

Table 36: Uncertainty summary

Driver	Classification	Description
Economic growth	Robust	Recommendations are robust to higher and lower economic growth. Relationships between waste and economic growth are contested but Commission analysis examines a range of scenarios which can be interpreted to reflect different rates of economic growth. In a high waste arisings scenario, total infrastructure investment is higher. However, the mix of infrastructure required to meet net zero is consistent across all scenarios so the risk of building the wrong infrastructure is minimal.
Climate change	Robust	Recommendations are independent of increases in global average surface temperature; they are appropriate across a range of temperature scenarios.
Technology and behaviour change	Strategic bet	The recommendation on reforming waste collection and increasing recycling rates presents a strategic bet on household behaviour. Outcomes rely on households adjusting their behaviour to take advantage of collection reforms and any enforcement measures used by local authorities to support these changes. Increasing incentives for investment in recycling infrastructure by banning future unabated energy from waste capacity is robust to technological and behaviour changes. Commission analysis assumes carbon capture and storage technology will be ready to deploy from 2030, and that the introduction of energy from waste into the emissions trading scheme from 2028 incentivises the switch to using carbon capture and storage technology. Commission analysis suggests that abated energy from waste capacity will grow. The mix of infrastructure and its associated costs have also been examined across high and low waste composition scenarios, reflecting possible changes in consumption behaviours. These scenarios have been examined because the composition of waste impacts its associated carbon footprint (for example, inert materials such as glass do not emit greenhouse gases when disposed). A high waste composition scenario may imply treating a higher proportion of high emitting material groups — food, plastics and paper and card — which is associated with a different set of costs.

Driver	Classification	Description
Population and demography	Robust	Recommendations are robust to a range of population growth scenarios, as reflected in the range of scenarios examined in the Commission's analysis.

Table 37: Sensitivities summary

Sensitivity	Description
Mix of treatment types	The combination of treatment types receiving waste flows may differ from the Commission's modelled scenarios. With each type of treatment facility charging a different gate fee, changes in the amount of waste treated in each facility type will affect the overall costs of waste management. Modelled scenarios capture high and low waste arisings and composition, which account for a degree of potential variation in the costs of waste management.
Unit cost assumptions	Costs were compiled based on both publicly available information and industry intelligence. A range of facilities were looked at, and an indicative cost per tonne was calculated based on the permitted tonnage for the facility and the cost of development. These were then averaged to provide a single value. Due to the wide range of facilities within the scope of the study, and the unique features which influence the cost of development of any project (for example geographic features such as water courses and mine shafts, transport costs for staff and materials based on site location, and economies of scale) Ricardo have provided all costs to a Class 5 classification of project definition.[198] At the level of the individual facility, this provides an expected accuracy range around capital and operating costs of -50 per cent to +100 per cent. This is broadly consistent with observed ranges around gate fees as reported in the WRAP gate fees report. [199]
Overall	Aggregate costs in the economic remit reflect each of the above sensitivities. It is unlikely that all high or all low sensitivities will compound across the whole industry, so the Commission assumes a plus or minus ten per cent range around its central estimates.

[198] AACE International (2005), 18R-97: Cost Estimate Classification System - As Applied in Engineering, Procurement, and Construction for the Process Industries
[199] WRAP Gate Fees report (2023), Gate Fees report 2022-23 | WRAP