The Second National Infrastructure Assessment

NATIONAL INFRASTRUCTURE COMMISSION

Better infrastructure for all

October 2023

Our remit

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

The Commission's objectives are to:

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

In fulfilling our purpose and objectives, we:

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

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

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Full biographies can be found towards the back of this report and on our website at nic.org.uk/about/the-commission/

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Foreword

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Sir John Armitt, Chair

Executive summary

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

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

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

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

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

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

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

The core recommendations the Commission is making to government include:

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

The National Infrastructure Assessment

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

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

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

The challenges ahead

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

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

Energy and net zero

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

Supporting growth across regions

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

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

Improving resilience and the environment

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

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

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

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

Energy and net zero

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

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

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

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

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

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

Building a secure, low carbon electricity system

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

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

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

Switching to electrified heat

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

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

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

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

Rolling out electric vehicles

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

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

New networks to support industry

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

Core networks of infrastructure to transmit and store hydrogen and carbon are essential by 2035. They will support industrial decarbonisation and provide the fuel needed to generate low carbon electricity. This carbon capture and storage system should have capacity to store at least 50MtCO_2e per year by 2035 and the core sites should cover Grangemouth and North East Scotland, Teesside, Humberside, Merseyside, the Peak District and Southampton. Similarly, the core hydrogen transmission network should connect Grangemouth and North East Scotland, Teesside, Humberside, Merseyside and South Wales.

Supporting growth across regions

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

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

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

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

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

Getting cities moving

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

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

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

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

Improving national road and rail networks

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

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

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

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

Enhancing digital connectivity

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

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

Improving resilience and the environment

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

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

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

Improving asset management and climate resilience

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

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

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

Improving the environment

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

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

Investing for the future

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

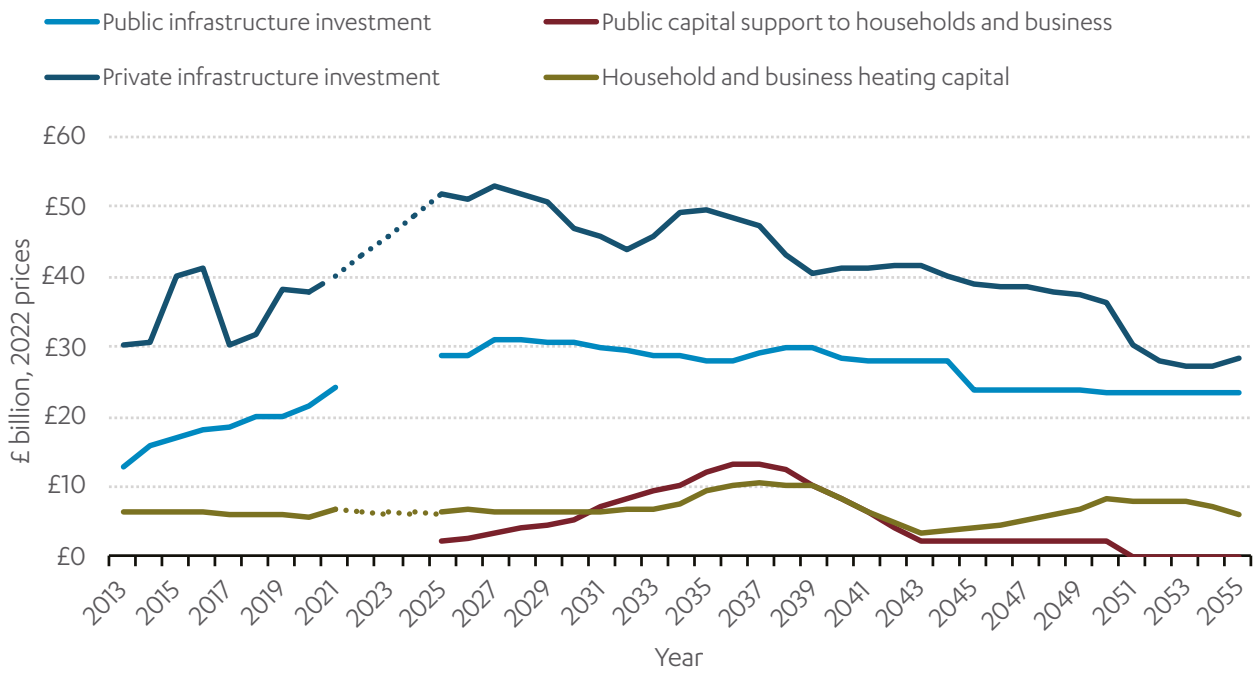
The Commission's analysis suggests that overall investment must increase from an average of around £55 billion per year over the last decade (around ten per cent of UK investment) to around £70 to 80 billion per year in the 2030s and £60 to £70 billion per year 2040s. Public sector investment will need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

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

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

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

Public and private investment in economic infrastructure from 2013 to 2055



Source: Commission analysis.

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

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

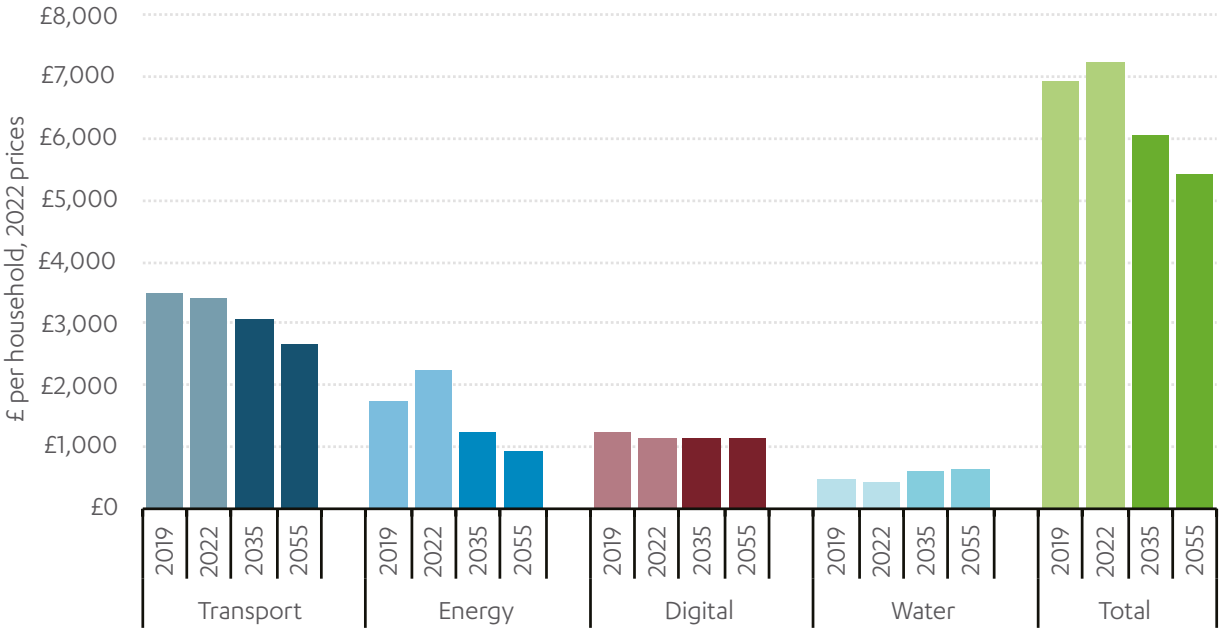
But making these investments will help lower costs for households and keep them low in the longer term. These upfront investments will be paid by consumers in their bills over the coming decades, not all at once.

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

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

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

Household spending on infrastructure 2019 to 2055



Source: Commission analysis

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

Making good decisions, fast

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

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

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

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

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

Further action is also needed to support investment, including:

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

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

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

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

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

There is no time to lose

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

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

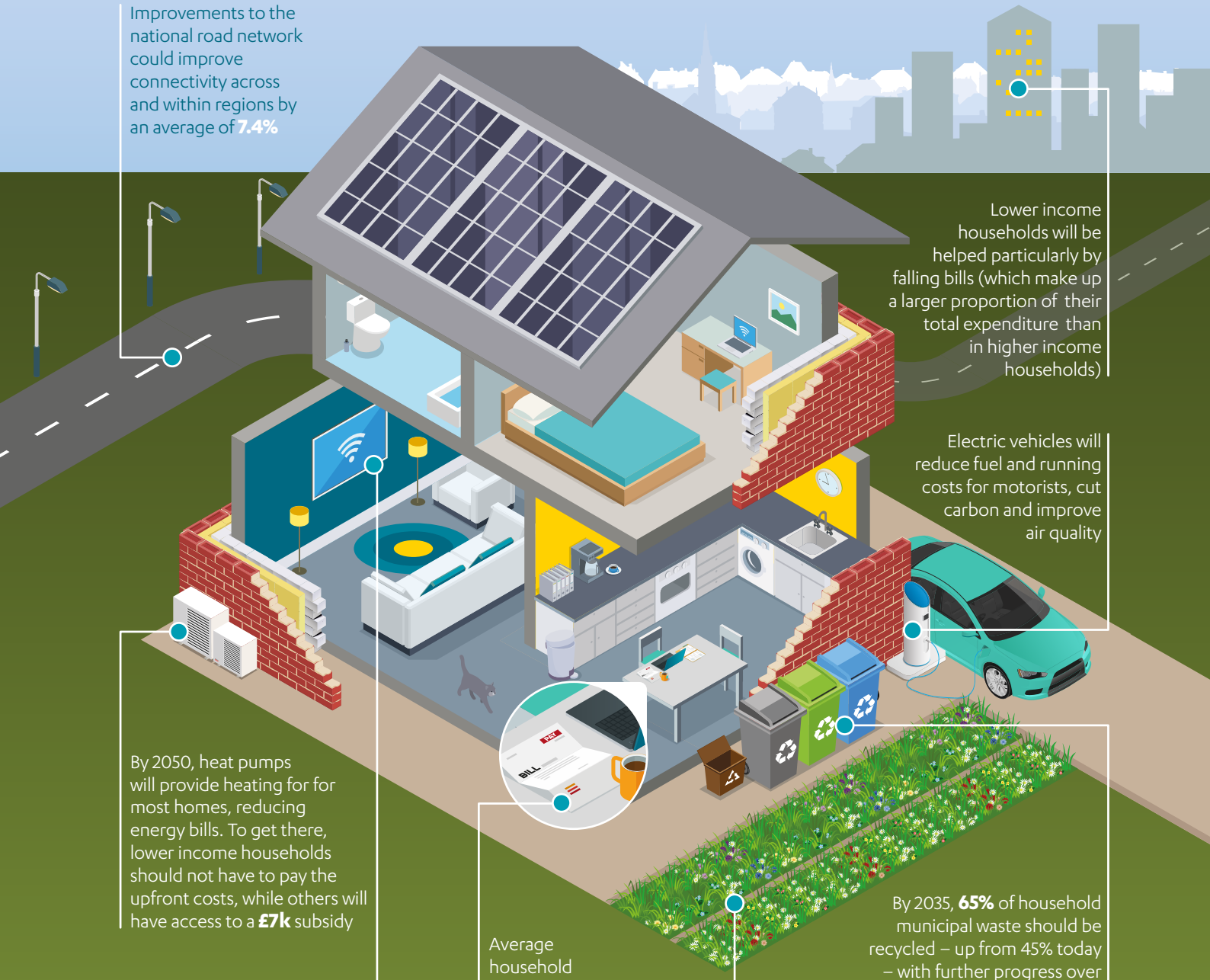
While meeting the UK's economic infrastructure needs will incur significant, if manageable, costs, the costs of inaction would almost certainly be greater. The UK has been here before: the inadequacies of infrastructure today reflect past failures to act and invest for the long term. Policies have too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

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

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

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

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



Engaging with stakeholders

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

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

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

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

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

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

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

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

Commissioners and senior staff spoke at 100 conferences and events

Source: Commission analysis. Numbers are approximate.

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

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

Highlights of the Commission's programme 2022 to 2023


London


Birmingham


Bristol

Manchester

1. The challenges ahead

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

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

How infrastructure performs today

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

- **Access to gigabit capable broadband:** The government has set out a clear vision to deliver gigabit capable broadband to at least 85 per cent of UK premises by 2025, and deliver nationwide coverage by 2030. Currently around 75 per cent of premises have gigabit capable broadband — up from five per cent in 2018.[2]
- **A shift to renewable electricity:** There has been a shift towards a highly renewable electricity system, with around 40 per cent of electricity generated by renewable sources in 2022 — up from less than ten per cent in 2010.[3]
- **Electric vehicles:** Following the Commission's recommendation that charging infrastructure should be delivered to support electric vehicles, sales of electric vehicles have increased sharply and government has put in place policy to phase out sales of new petrol and diesel cars.[4]
- **Flooding:** Between 2021 and 2027 the government has committed to investing £5.6 billion to reduce the risk of flooding.[5]
- **Drought resilience:** Government and the water industry in England have taken on the Commission's recommendations to increase water supply and reduce leakage, although a lot more still needs to be done.[6]
- **The UK Infrastructure Bank:** In June 2021, government launched the independent infrastructure financing institution the Commission recommended be established following the UK's loss of access to the European Investment Bank.[7]
- **Transport devolution:** Following the Commission's recommendation that there should be greater devolution of transport budgets, government established the five year City Region Sustainable Transport Settlements for Combined Authorities.[8]

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

- little progress has been made to decarbonise heat, although the technologies to do so already exist
- emissions from transport have not been declining (Figure 1.2), despite improvements in engine efficiency, and, although electric vehicle charge point numbers are increasing,[9] the pace needs to accelerate to enable the transition to electric vehicles
- asset maintenance issues undermine performance in some sectors, including ageing and leaky water pipes and potholes in local roads[10]
- about 900,000 properties in England have a more than one per cent chance each year of being flooded by rivers and the sea and around 910,000 properties have a more than one per cent chance of flooding from surface water[11]
- the number of serious pollution incidents caused by water company assets remains unacceptably high; moreover in 2021 only 16 per cent of water bodies achieved good ecological status[12]
- no major water supply reservoirs have been built in the last 30 years to tackle the increasing risk of drought[13]
- recycling rates have plateaued and emissions from waste remain too high, while the total waste generated in England is increasing[14]
- in many major regional English cities it takes too long to reach city centres[15]
- there are too many journeys between towns and cities on major roads across England that are slow or indirect, creating barriers to trade.[16]

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

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

Taking advantage of strategic opportunities

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

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

These are linked to the Commission's own objectives to: support sustainable economic growth across all regions of the UK, improve competitiveness, improve quality of life, and support climate resilience and the transition to net zero carbon emissions by 2050.[23]

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

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

Devolved administration responsibilities, by infrastructure sector

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

Source: Commission analysis of devolution legislation and agreements

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

Energy and reaching net zero

To create a net zero economy by 2050 the UK needs to move away from gas and oil. To meet its legally binding climate targets, the UK must reduce its overall greenhouse gas emissions by 78 per cent compared to 1990 levels by 2035, and to net zero by 2050.[24] Good progress has been made: greenhouse gas emissions in 2022 were around 45 per cent lower than in 1990.[25] However, the vast majority of recent progress has been driven by decarbonising electricity generation,[26] while in other sectors, progress has been much slower (see Figure 1.2).[27] Urgent action is needed to put the UK on track to meet the Sixth Carbon Budget and achieve a net zero economy by 2050.[28]

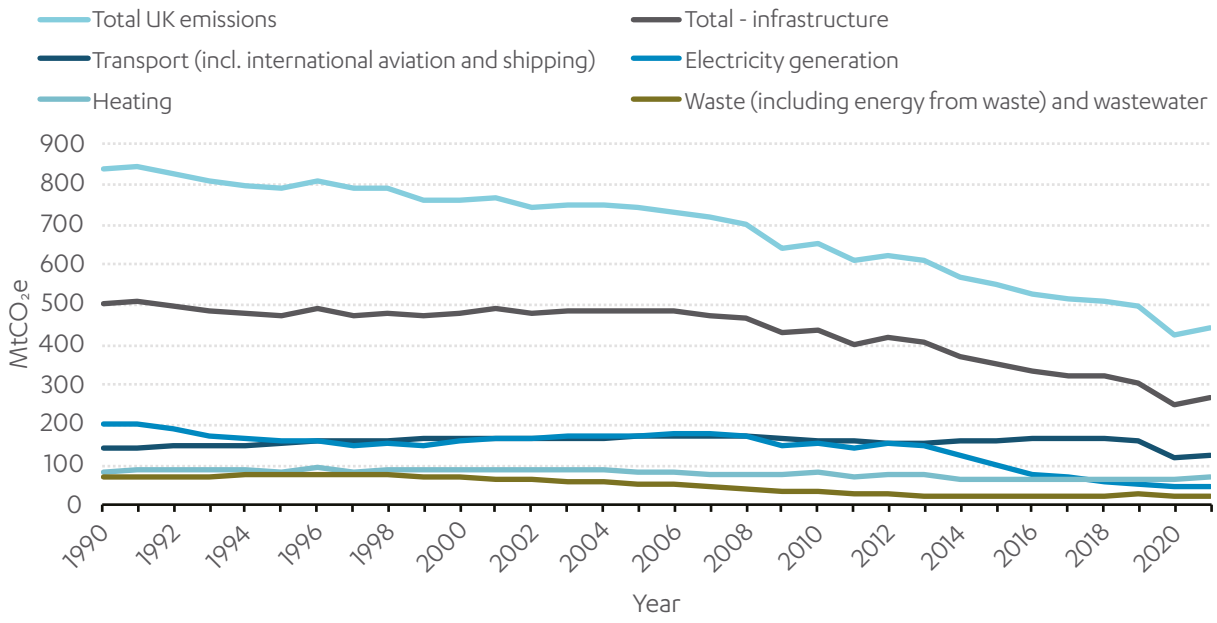
Over two thirds of the UK's greenhouse gas emissions come from economic infrastructure:

- 55 $MtCO_2e$ (15 per cent) from generating electricity, which needs to fall to less than 10 $MtCO_2e$ by 2035
- 90 $MtCO_2e$ (20 per cent) from heating buildings, which needs to fall to around 45 $MtCO_2e$ by 2035
- 100 $MtCO_2e$ (25 per cent) from fueling vehicles, which needs to fall to around 50 $MtCO_2e$ by 2035
- 75 $MtCO_2e$ (20 per cent) from powering industry, which needs to fall to around 20 $MtCO_2e$ by 2035.[29]

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

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

Annual greenhouse gas emissions by infrastructure sector, 1990 to 2021



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

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

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

Supporting growth across all regions

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

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

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

- England's largest regional cities are congested, and their public transport networks underperform relative to comparable European cities[40]
- there are wide variations in interurban connectivity between similar places,[41] with rail journeys between major cities in the Midlands and the North often slow, and the services unreliable.[42]

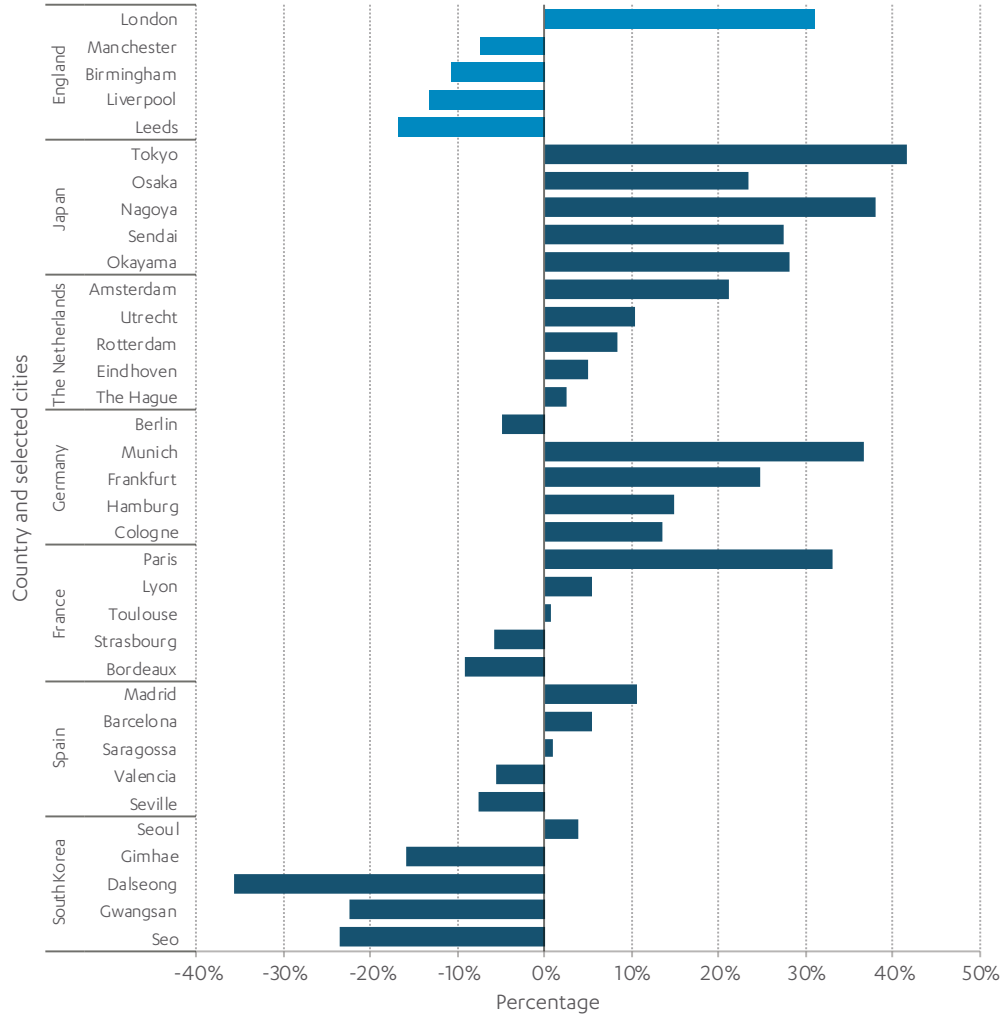
The quality and reliability of public transport in major cities needs to be brought much closer to that of London. At the same time, London's transport system must be maintained at its world class level, given the important role London plays both regionally and nationally. Improving strategic road and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

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

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

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

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



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

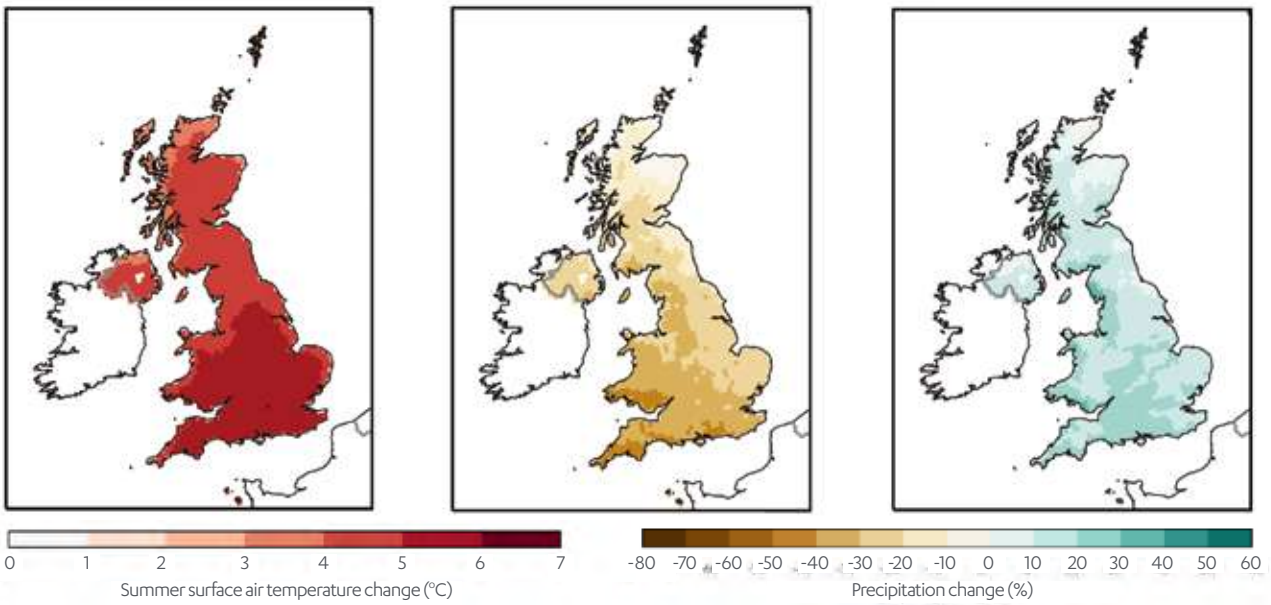
Improving resilience and the environment

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

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

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

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



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

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

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

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

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

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

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

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

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

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

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

Making good infrastructure policy

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

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

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

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

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

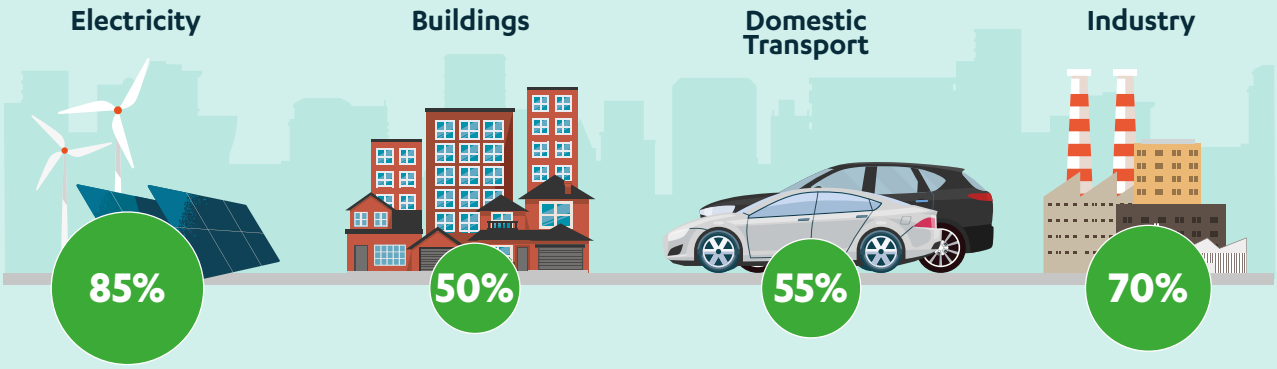
The Commission has produced and commissioned extensive and wide ranging analysis to support the development of the recommendations in this Assessment. The Commission's Young Professionals Panel has also produced a separate report setting out their own priorities for future infrastructure. Their proposals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

2. Energy and reaching net zero

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

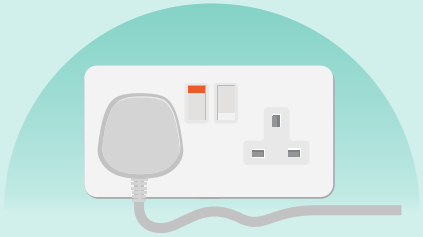
Currently, around 80 per cent of the UK's energy demand is met by fossil fuels

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



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

Significant changes to the energy system will be needed

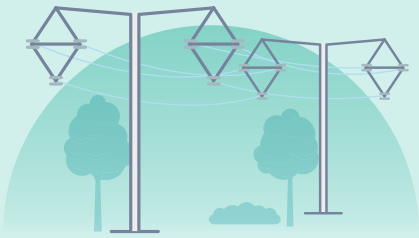


Electricity demand in Great Britain will increase by around **50%** by 2035

A **35%** annual growth rate in **heat pump** installations is needed to decarbonise **7 million buildings** in England by 2035

A **30%** a year growth in deployment is needed to deliver **300,000 public electric vehicle charging points** in the UK by 2030

Hydrogen and carbon capture and storage **networks** by 2035



17 additional **electricity transmission projects** need to be completed by 2030

Sources: DESNZ, Aurora, Commission modelling, DfT

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

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

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

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

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

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

The challenge ahead

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

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

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

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

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

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

- in the 1950s, an electricity 'supergrid', comprising 4,000 miles of transmission lines, was built in 12 years[72]
- in the 1960s and 70s, all gas appliances were converted from town gas to natural gas in ten years[73]
- in the 1990s 'dash for gas', the UK built around 40 gas power stations, equivalent to 20GW of capacity in ten years, with a maximum annual rollout of three GW.[74]

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

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

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

Building a secure, flexible and low carbon electricity system

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

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

Decarbonising electricity requires rapid and decisive changes, including:

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

Low carbon electricity generation

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

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

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

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

A flexible electricity system

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

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

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

Box 2.1: Defining flexible technologies

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

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

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

The electricity system needs flexible technologies that can provide both enough capacity and enough volume of energy. **Capacity** is measured in gigawatts (GW). This is a measure of how much energy a technology can transfer at any one point in time. **Volume** of energy is measured in terawatt hours (TWh). This is a measure of how much energy a technology can transfer over a specified period of time. One TWh is equal to a technology with one GW capacity running for 1,000 hours. For storage technologies, TWh is a measure of how much energy the technology can output before it is empty and needs to be recharged.

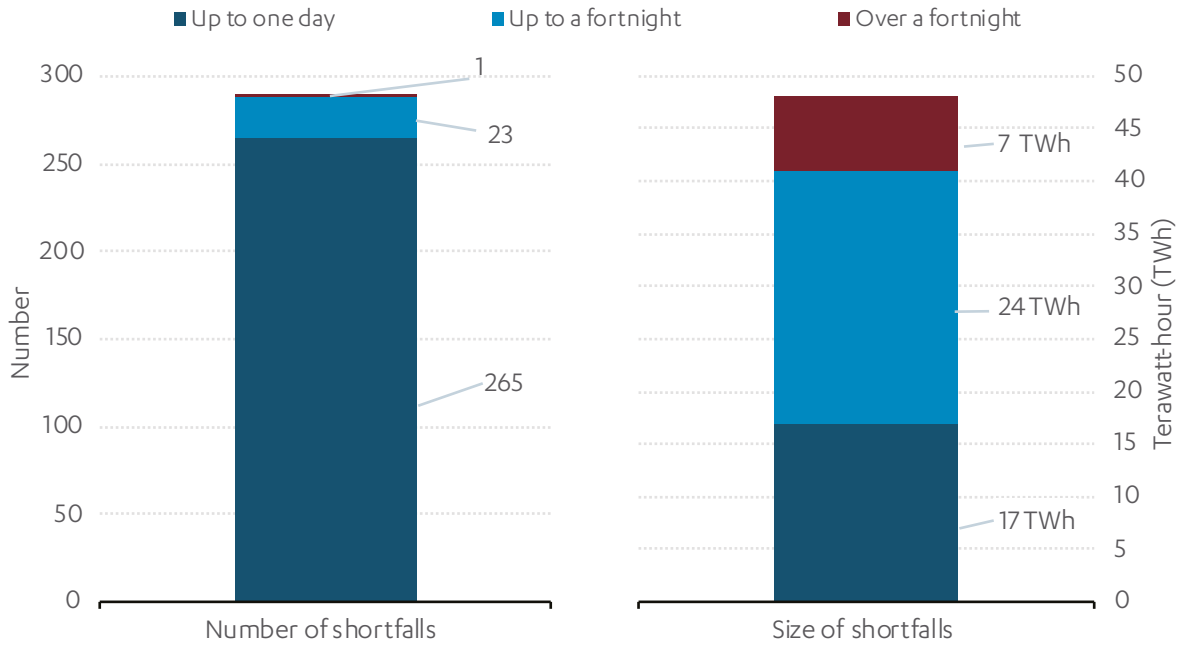
A range of technologies will replace the role of unabated gas fired generation in providing flexibility to the electricity system. The optimum technologies to use will vary depending on the time period:

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

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

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

Number and size of shortfalls in an illustrative 2035 scenario



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

By 2035, modelling for the Commission suggests that 60GW of short term flexible capacity will be needed to provide a low cost electricity system.[87] There is currently around 15GW of low carbon supply side flexibility on the system.[88] The technologies that provide short term flexibility have different characteristics, so a portfolio of technologies will offer benefits to the system while minimising deployment risks. To support an efficient highly renewable system, two thirds of this target may be needed by 2030.[89]

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

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

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

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

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

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

At least eight TWh of hydrogen storage capacity will be needed by 2035.[100] This will provide enough storage to manage winters that are colder and less windy than average, providing additional resilience when there is lower renewable generation output or higher energy demand. Considering the possibility of several winters that are colder and less windy than average over multiple years could significantly increase the storage capacity that might be needed.[101]

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

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

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

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

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

An end to unabated gas fired generation

To fully decarbonise electricity generation, unabated gas fired generation must end. By 2035, actions to meet renewable generation targets and scale up flexible low carbon technologies should allow the contribution of unabated gas fired generation to fall to no more than two per cent of generation.[105] The UK has successfully taken action to reduce coal generation from 39 per cent of electricity generated in 2012 to two per cent by 2021.[106] Similar policies can drive the same reduction in unabated gas fired generation.

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

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

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

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

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

Transforming electricity networks

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

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

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

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

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

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

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

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

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

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

Increasing resilience

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

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

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

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

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

Switching to electrified heat

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

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

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

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

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

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

Heat pumps are the most efficient way to heat buildings

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

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

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

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

Improving efficiency will reduce energy demand

Government's ambition is to reduce energy demand from buildings and industry by 15 per cent (from 2021 levels) by 2030.[142] New policies are needed to deliver government's ambition, reduce energy bills by reducing the energy used to heat buildings, and to alleviate the broader consequences of ill health caused by cold homes, including the burden this has on the NHS.[143] Improving energy efficiency will also reduce the demands on the energy system.

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

Households on lower incomes, those in vulnerable circumstances and those with protected characteristics (which mean their energy demand is higher than average) could stand to benefit the most from improved energy efficiency but are also least likely to be able to afford it. Financial support for improving energy efficiency targeted at lower income households, including those living in social housing, can support these groups.[144] To deliver this, government should extend existing support mechanisms, such as the Energy Company Obligation[145] (which requires energy companies to deliver improvements to the least energy efficient homes and targets lower incomes) and the Social Housing Decarbonisation Fund,[146] and outline a plan for tightening regulations for the private rented sector.[147] In relation to budgets for social housing improvements, delivery of devolved multiyear funding packages to local authorities to support social housing providers in their area should be used rather than the existing approach of competitions for available funds.

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

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

Long term funding to deliver heat decarbonisation

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

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

Government has committed to reducing emissions from the public sector by 75 per cent (from 2017 levels) by 2037.[148] Government now needs a programme that can effectively deliver this commitment. This should involve long term devolved budgets for departments and local government to decarbonise the parts of the estate they are responsible for rather than the current approach of competitive bidding processes for funding individual schemes. Public sector decarbonisation also presents an opportunity to modernise schools, hospitals and other buildings, improving ventilation, offering resilience to hotter weather and ultimately lowering bills.

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

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

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

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

Incentives to switch to low carbon heating can be strengthened

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

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

Box 2.3: International market for heat pumps

Other countries have successfully accelerated heat pump uptake through a combination of government policies and incentives. This has included subsidies or tax rebates for installations, low cost loans, bans on new connections to the gas network, building standards and favourable electricity prices. Between 2018 and 2021 the Netherlands and France have each seen average year on year growth of 27 per cent. Average growth in Poland has been 48 per cent, with a high of 61 per cent year on year growth in 2021.[154]

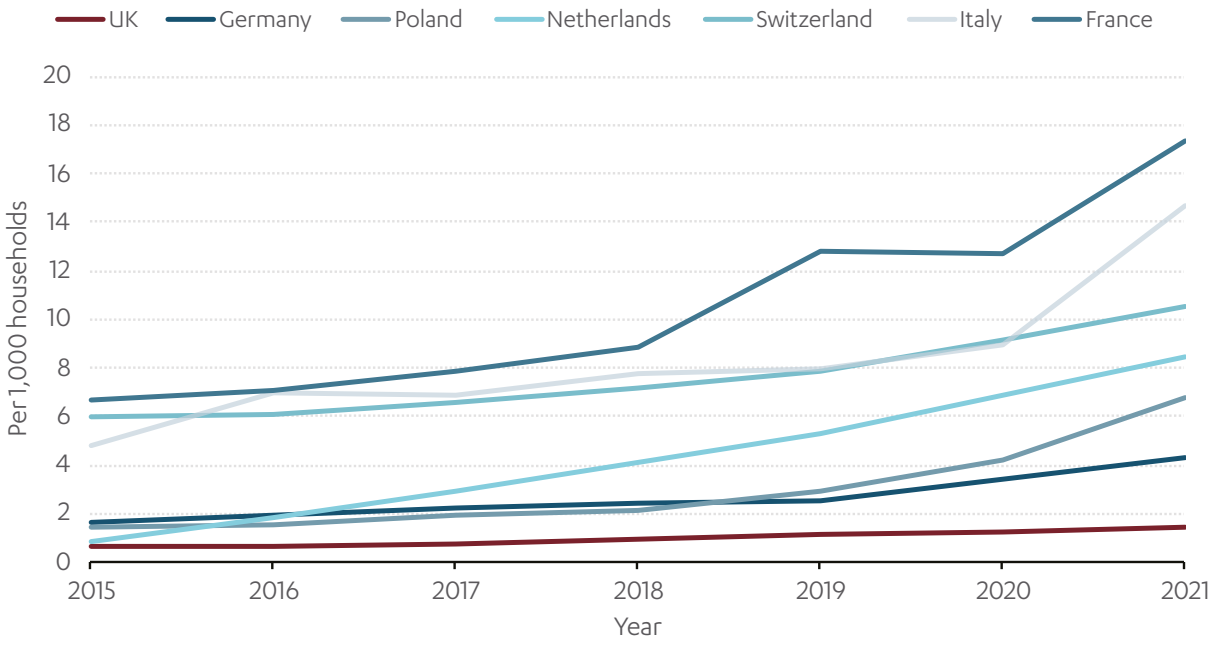
In the **Netherlands** there are low interest loans as well as a grant for heat pumps. The grant runs up to 2030 providing long term certainty to households and businesses. There has also been a ban on new connections to the gas network since 2018 and new fossil fuel boilers will be banned in 2026.[155]

In **France** a mixture of grants and zero interest loans are available to households for heat pumps and energy efficiency. New gas connections and replacement oil boilers were banned in 2022.[156]

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

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

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



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

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

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

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

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

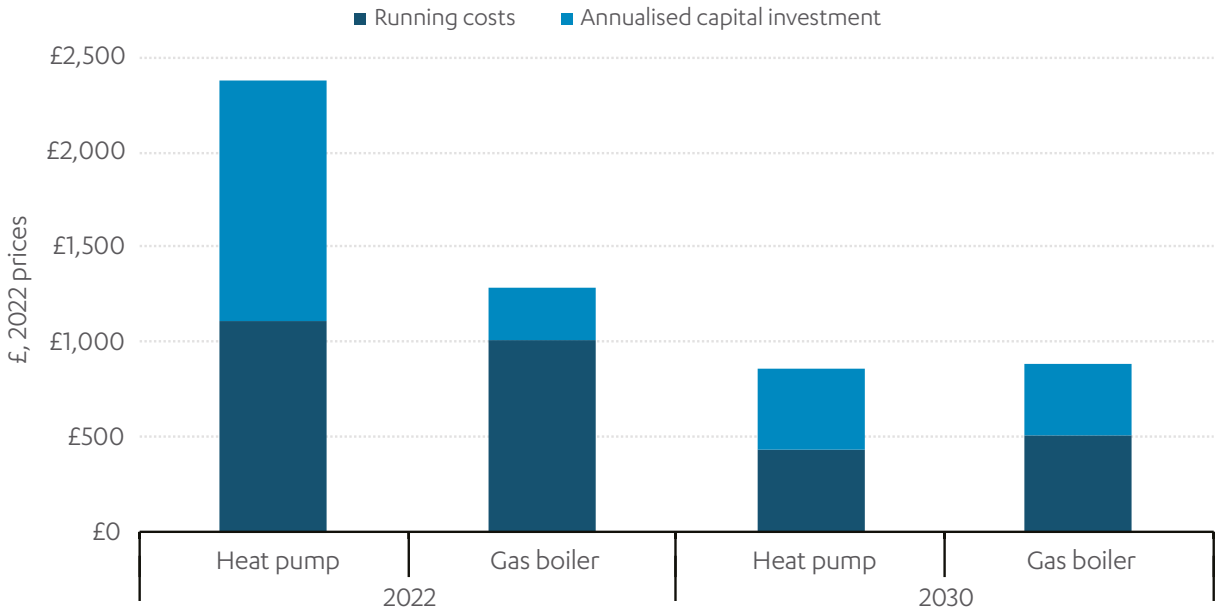
Increasing the subsidy will still leave most households, building owners and small businesses needing to pay roughly half the cost of a heat pump installation (based on current average costs). There will be many that do not have access to savings to cover this additional upfront cost and cannot access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

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

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

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

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



Source: Commission analysis

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

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

- alleviating planning permission restrictions on the location of heat pumps by amending the Town and Country Planning Act Schedule 2, for example to change the rule that all parts of the heat pump must be at least one meter from the property boundary[166]
- standardising when installing a heat pump requires approval from the electricity distribution network operator, and when installers can upgrade a house's fuse
- considering changes to permissions and access rules, e.g. loosening restrictions on installing heat pumps in listed buildings, reducing restrictions on what leaseholders can do and granting wayleaves for hot water pipes to support heat network rollout
- improving consumer awareness of the need to transition to low carbon heat and the changes needed.[167]

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

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

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

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

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

Hydrogen's role in heating

Hydrogen heating has been proposed as an option to provide low carbon heat. It would use a gas style boiler and would require low carbon hydrogen to be produced in large quantities and be delivered via a network of pipes to buildings. Hydrogen is low carbon when produced via electrolysis, or through reforming natural gas if the carbon emitted in the process is captured and stored. Government has said it will decide on hydrogen's role in heating in 2026.[170]

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

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

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

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

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

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

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

Source: Commission analysis

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

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

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

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

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

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

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

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

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

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

Fossil fuel heating should be phased out

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

To phase out fossil fuel heat, firstly, government should not allow new buildings to connect to the gas network. Households and businesses should not be locked into options that have a finite life.[178] Government should also use regulation to end the use of fossil fuel heating in some sectors in the near term. Large commercial buildings (those over 1,000m^2) account for around ten per cent of emissions from buildings, despite making up less than one per cent of the building stock.[179] Targeting regulation at this sector, which is most likely to be able to respond and take advantage of the changing relative prices of gas and electricity, would mean fewer buildings will need to switch in other parts of the building stock which are more challenging to decarbonise.[180]

Government has an ambition to start phasing out the sale of new fossil fuel boilers by 2035.[181] The Commission recommends that from 2035 no new fossil fuel boilers are sold. This will provide clarity to households and certainty to businesses that will be investing in low carbon heating technologies and the workforce needed to install them. A strong commitment to this date, ensuring that it does not slip back, should help drive take up of heat pumps and limit the number of households and businesses that have to change working fossil fuel boilers in 2050 when they will no longer be served by a gas supply in order to meet government's net zero commitment.[182] Government has been successful in driving the transition to electric vehicles and can apply the same approach to setting long term policy to support the heat transition. In driving the switch to electric vehicles, it:

- signalled an end date for the sale of new petrol and diesel cars and vans well in advance[183]
- led the way in decarbonising its own fleet of vehicles[184]
- established policy to build the supply chain[185]
- provided financial support and other incentives including for charging infrastructure.[186]

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

Box 2.4: Learning lessons from the town gas conversion

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

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

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

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

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

- providing democratic input to decisions made about the sequencing of gas disconnections
- scrutinising the input into these decisions from the gas and electricity network operators who will be the bodies that deliver the infrastructure changes that are needed, with the support of the proposed Regional System Planners[190]
- playing a role in protecting households and businesses, particularly those in vulnerable circumstances, through the transition.

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

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

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

Rolling out electric vehicles

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

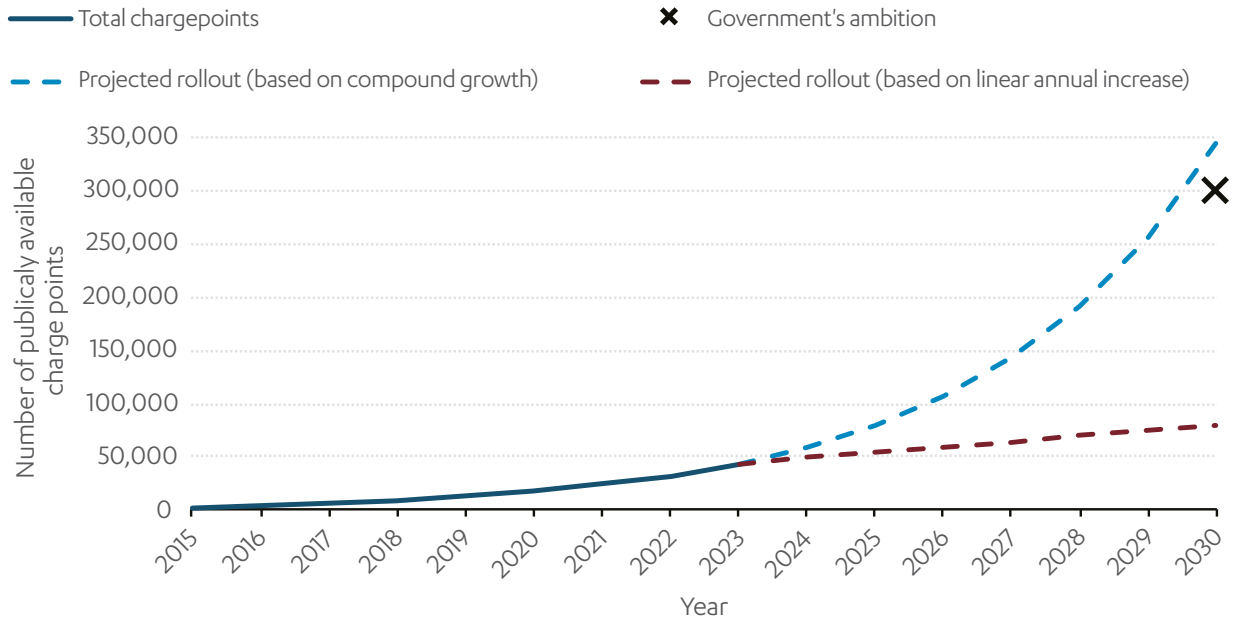
Deploying electric vehicles

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

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

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

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



Source: Department for Transport (2023), Electric vehicle charging device statistics (July 2023)
Note: Annual charge point total is based on data from July of each year.

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

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

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

Adaptive plans for transport decarbonisation

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

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

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

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

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

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

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

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

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

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

New networks to support a thriving economy

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

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

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

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

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

Industrial point source emissions by area ($MtCO_2e$), 2020

Cluster location	Industrial point source emissions ($MtCO_2e$)	Cumulative per cent of industrial point source emissions
Humberside	8.9	18%
South Wales	6.4	31%
Merseyside	4.5	41%
Grangemouth	4.1	49%
Teesside	3.4	56%
Southampton	3.0	62%
Peak District	2.9	68%

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

Incentivising the switch to low carbon energy

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

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

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

Developing core networks

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

Policy to support development of infrastructure is not moving forward at the pace needed. Government has started the process of supporting carbon capture and storage infrastructure at four industrial hubs with the aim to have them operational by 2030.[218] For hydrogen pipelines and storage, government has recently issued an update on its plans, but support arrangements are not set to be agreed until 2025.[219]

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

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

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

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

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

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

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

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

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

A core network for carbon pipelines and storage

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

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

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

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

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

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

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

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

Recommendation 15: Government should commit to the development of a carbon transmission pipeline and storage network that can transport and store at least 50MtCO_2e per year by 2035. The actions needed to deliver this are:

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

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

A core network for hydrogen pipelines and storage

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

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

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

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

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

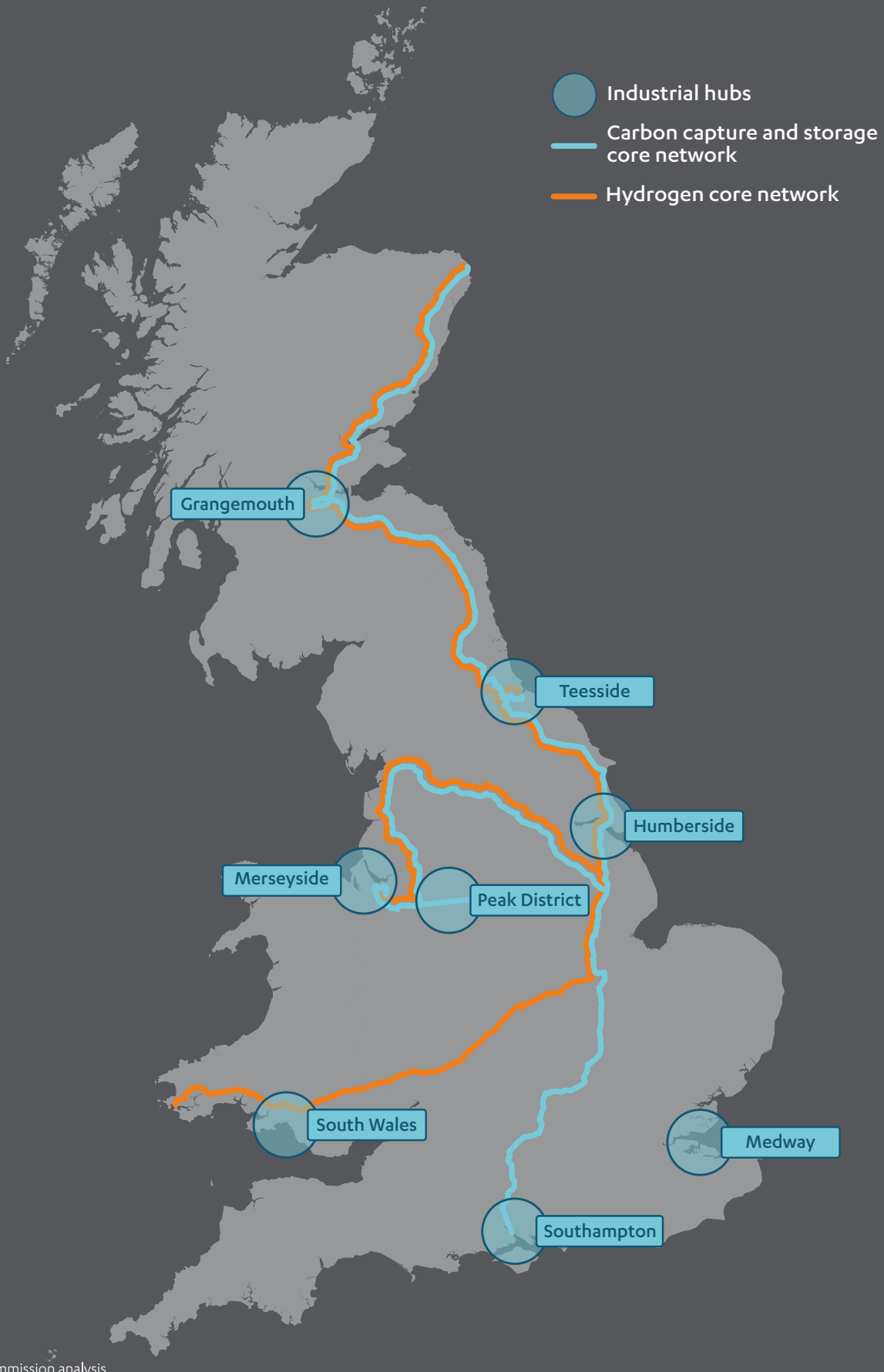
Recommendation 16: Government should commit to the development of a core hydrogen pipeline network that is operating no later than 2035. The actions needed to deliver this are:

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

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

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

Core pipeline networks for hydrogen and carbon



Source: Commission analysis