The Journey to Net Zero

Chapter 2

1. Transforming the UK's economy over the next three decades to reach net zero will be a journey of unprecedented opportunity and change. Our greenhouse gas emissions have fallen by more than two-fifths in the last thirty years, with particular progress in the decarbonisation of our electricity system, but we need to go further and faster in the next thirty years, right across the economy.[1] It will mean developing and rolling out new, innovative, and climate resilient technologies; embracing new ways of doing things – from new ways of travelling, heating our homes, and using our land; and creating new industries and jobs through our green industrial revolution.

2. The policies to drive these changes, and the opportunities arising for individuals and the UK economy, are set out across the remaining chapters of this Strategy. This chapter first explores what reaching net zero by 2050 could mean for the UK; potential scenarios of how we will get there; and an indicative pathway to deliver on our ambitious carbon budgets along the way, while navigating the inherent uncertainty. We look at this journey from a whole-economy perspective, considering the key interactions between sectors, technologies and the energy system that need to be planned for as we decarbonise.

The UK's Net Zero Future

Our **industrial heartlands** are reinvigorated, with **innovation** and **private investment** in clean technologies – such as wind, carbon capture and hydrogen in multiple locations across the UK including the North East; or the manufacture of batteries and electric vehicles in the Midlands.

Our **green economy** and its **supply chains** provide sustainable jobs for highly-skilled workers – in construction, manufacturing, engineering, science, nature conservation, finance and more, across the economy and the UK, including in rural areas.

Our **businesses** are delivering the latest low carbon technologies, services and innovations for the UK and export markets; and are more resilient to the global net zero transition.

Our **homes** are warm and comfortable, powered and heated by clean, affordable energy.

Our **journeys** are made in zero emission vehicles, with trains, ships and planes running on new low carbon energy sources.

Our **towns and cities** have cleaner air for everyone, and support walking and cycling with benefits for health.

Our **goods** are designed to last longer and be more efficient, while being used, repaired and remanufactured within a circular economy.

Our **natural environment** is protected, enhanced, and more diverse, with healthy ecosystems and increased biodiversity, supporting a sustainable rural economy and providing wider benefits, including improved mental health and protection from risks like flooding and overheating.

A systems approach to the net zero journey

3. The characteristics of the net zero challenge – requiring action by multiple parties across the public and private sectors, delivery at pace, and management of large uncertainties – underline the need for strong coordination in policy development and clear signalling to markets. Government taking a systems approach to policy will help to navigate this complexity. We must consider the environment, society, and economy as parts of an interconnected system, where changes to one area can directly or indirectly impact others. This will help to ensure we design policy to maximise benefits, account for dependencies, mitigate conflicting interests and take account of learning as we go. It reduces the risk of unintended consequences, ensuring individual decisions designed to help achieve net zero do not end up hindering it or other important objectives.

4. A systems approach does not attempt to design a 'perfect' net zero end-state thirty years into the future. It aims to enable innovative and desirable solutions to be developed, and to ensure that decisions are made when needed, based on the best evidence available at that time and with the fullest possible range of considerations brought to bear. This includes taking a dynamic approach to policymaking and updating our assumptions on an ongoing basis; considering public reactions to a policy; accounting for where a particular investment or technology deployment may affect another sector's decarbonisation; and considering the net costs and benefits across different parts of the economy and environment.

5. We have implemented several key elements of a systems approach, including:

- Establishing forums for delivering shared net zero goals and identifying key issues through cross-system governance structures, including two new Cabinet committees;
- Working towards a shared understanding of interdependencies and risks across different parts of the net zero challenge, for example through £2 million funding from the Shared Outcomes Fund to develop systems tools;
- Testing and determining feasible net zero scenarios with our whole energy systems modelling suite, and supporting our work to identify high leverage, systemic actions such as CCUS that will be necessary in a wide range of scenarios.

6. Work will continue to develop this approach further. This Strategy encompasses changes from across the system that will need to be delivered to achieve net zero.

7. As summarised in Figure 3 below, each sector of the economy will play a vital role in the future net zero system, and these are highly connected – changes in one area can directly or indirectly impact others.

8. Applying a systems approach to policymaking can help to address complex policy challenges, including to identify interdependencies. The case study below for electric vehicles demonstrates the need to understand the complex interactions which drive change. Government will continue to test and update its understanding of systems and how they relate to one another, which forms an important part of how we will monitor delivery, explored further in the *Embedding net zero in government* chapter.

Figure 3: The role of each sector in the future net zero system

Natural Resources & Waste

Role of sector: land provides both energy sources and natural carbon sinks, while polluting areas, including agriculture and the treatment of waste, must decarbonise.

Relationship with other sectors: depends on developing new ways of using land sustainably, while end uses like agricultural machinery will rely on low carbon energy.

Power

Role of sector: generates electricity to meet low carbon energy demand across all sectors.

Relationship with other sectors: depends on demand across end use sectors, while specific forms of generation can use carbon capture technology, hydrogen, and waste.

Greenhouse Gas Removals

Role of sector: alongside natural carbon sinks, engineered removals deliver negative emissions, either directly from the air or as a co-benefit of methods to generate power, fuels and products.

Relationship with other sectors: compensates any residual emissions to ensure a net zero system. Engineered removals also use electricity.

Industry

Role of sector: develops cleaner ways to produce the wide range of products we all rely on, from food and drink to iron and steel.

Relationship with other sectors: depends on low carbon energy supply from power and hydrogen, as well as the use of carbon capture technology alongside power, hydrogen and greenhouse gas removals.

Heat & Buildings

Role of sector: our public, business, industrial and residential buildings, as well as products we use for cooking and everyday living, move to green forms of energy.

Relationship with other sectors: depends on low carbon energy, while different heat options will in turn affect the development of supply sectors.

Transport

Role of sector: all forms of travel that keep modern society moving – road, rail, aviation, and shipping – run on green forms of energy.

Relationship with other sectors: depends on low carbon energy, while different transport options will in turn impact the development of supply sectors.

Fuel Supply & Hydrogen

Role of sector: supports energy supply, especially in areas that are harder to electrify such as heavier transport. Oil and gas play a far reduced role where needed and abated by carbon capture technology where possible.

Relationship with other sectors: depends on demand across end use sectors, while different types of hydrogen production use electricity, carbon capture, and biomass.

Case study of a 'systems approach': Electric Vehicle (EV) roll out

The transition to EVs is central to decarbonising road transport. Higher sales of EVs means overall electricity demand will increase, requiring greater electricity generation and grid capacity. Over the lifetime of an EV, overall carbon emissions are already significantly lower than a traditional internal combustion engine car and, as the electricity grid continues to decarbonise, the lifetime of emissions from driving an EV reduce. The transition to EVs therefore has a potential knock-on impact on the industrial sector and its wider supply chains, particularly in certain regions of the UK, for example creating additional demand for new wind turbine manufacture and installation.

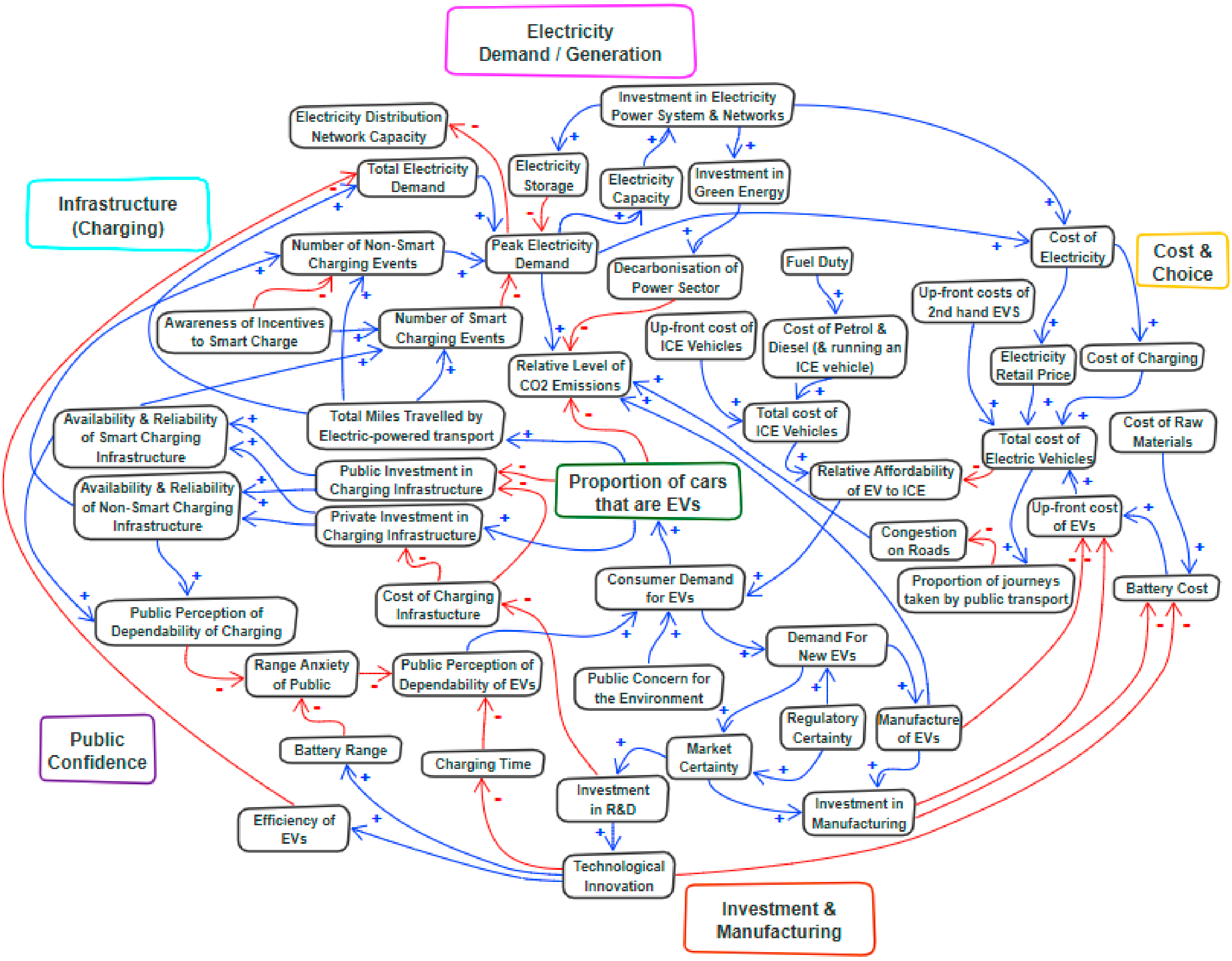
More EVs will affect both the scale and nature of electricity demand, including the timing and scale of peaks, as patterns of charging behaviour develop (e.g. many people choosing to charge at the end of the working day). The changes this could bring need to be carefully thought through, and opportunities seized. For example, innovative technology could support smoothing of electricity demand, by allowing electricity stored in batteries to be fed back into the grid at times of low renewable generation or high demand (vehicle-to-grid technology). Smart charging (enabled by regulations that Government plans to lay later this year) will also help to move demand away from peak times as well as helping consumers to benefit from lower cost off-peak electricity.

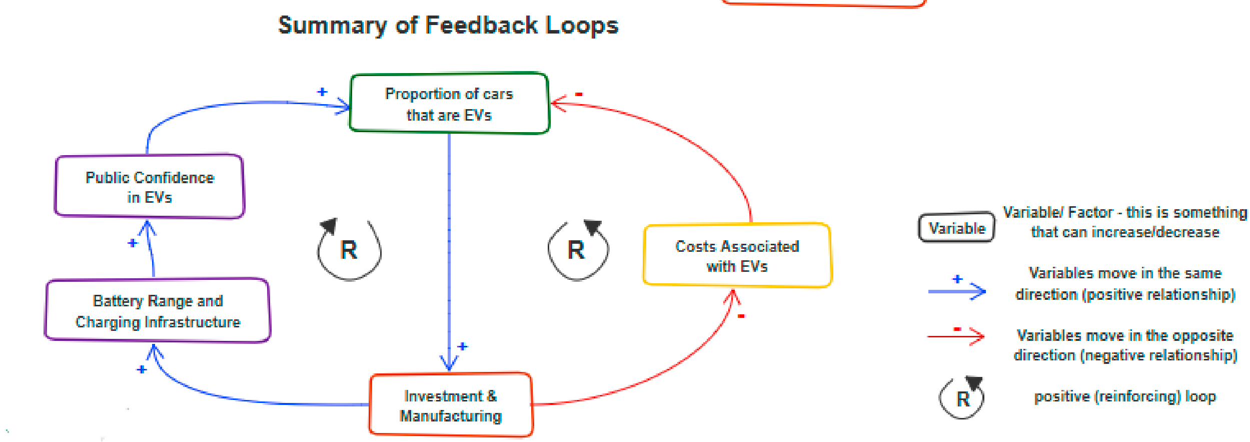
The roll out of EVs will have an impact on demand for petrol and diesel, with potential to impact through the supply chain, from production to processing, distribution and retail. Uptake will also have an impact on R&D, investment, and manufacturing of both EVs, and the infrastructure required to use them. The effect of investment in these areas would be wider availability of the infrastructure required for charging, reduction in the cost of manufacturing, and further advances in EV technology.

Manufacturing costs will likely fall as production increases at scale and investment in R&D will bring down the costs of components. Wider availability of reliable charging infrastructure should remove range anxiety for EV drivers and streamlining payment methods should improve the consumer experience. These two factors will then encourage further take up of EVs with these sets of relationships representing positive feedback loops.

The examples above are a significant simplification of some of the interactions between sectors as EV roll out progresses. The below systems map shows a more granular picture, though this is also a simplification and some variables will have other influences that are not displayed here.

Figure 4: Example of a 'systems map' showing some interactions to consider in the roll out of electric vehicles





Pathways to net zero by 2050

Key features of the net zero transition

9. There are a range of ways in which net zero could be achieved in the UK. Our exact route will depend on the availability and deployment of key technologies, supported by long-term market growth, as well as the extent to which individuals and businesses adopt green choices. Our approach must consider physical factors, such as land availability and climate change risks like drought and flooding. As a principle, we will pursue options that leave the environment in a better state for the next generation by improving biodiversity, air quality, water quality, natural capital, and resilience to climate change where appropriate.

10. As we increase our efforts to decarbonise domestically, we must ensure production, and the associated greenhouse gas emissions, does not shift to other countries with lower climate obligations. In the *Net Zero Review* we consider the carbon leakage risk facing UK businesses on a sectoral basis and discuss the approaches to help address this risk.[2] In addition to encouraging our trading partners to increase their own efforts, we are engaging with industry to better understand the risks and consider the full range of options to address these, including through the UK Emissions Trading Scheme, discussed further in the *Industry* chapter.

11. While there are significant costs in reaching net zero, the cost of inaction is much higher. The Office for Budget Responsibility's recent report showed unmitigated climate change resulting in "debt spiralling up to around 290% of GDP thanks to the cost of adapting to an ever hotter climate and of more frequent and more costly economic shocks".[3] In addition to reducing the risks of catastrophic climate change, net zero will also bring significant benefits and opportunities, such as economic growth and jobs in new green sectors, reducing air pollution with benefits for health, and enhancing biodiversity. We also expect costs to continue to fall as green technology advances, industries decarbonise, and private sector investment grows. Recent cost benefit analysis for the sixth carbon budget[4] suggests that the significant benefits of net zero more than offset the costs, resulting in a net benefit.

12. Most costs are the additional capital costs (and associated financing) of low carbon technologies, although significant fuel savings help to offset these. We estimate that the net cost, excluding air quality and emissions savings benefits, will be equivalent to 1-2% of GDP in 2050. Our approach will need to reflect that benefits and impacts of the transition will be dependent on individual household characteristics, such as their housing type and current vehicle usage, to support those low-income households most affected by individual technology transitions. The government's approach will also support the principle that those who produce the pollution should bear the costs of managing it. Further information on the economic impacts is set out in HM Treasury's *Net Zero Review*, which informs our approach to achieving a transition that works for households, businesses and public finances, and maximises economic growth.

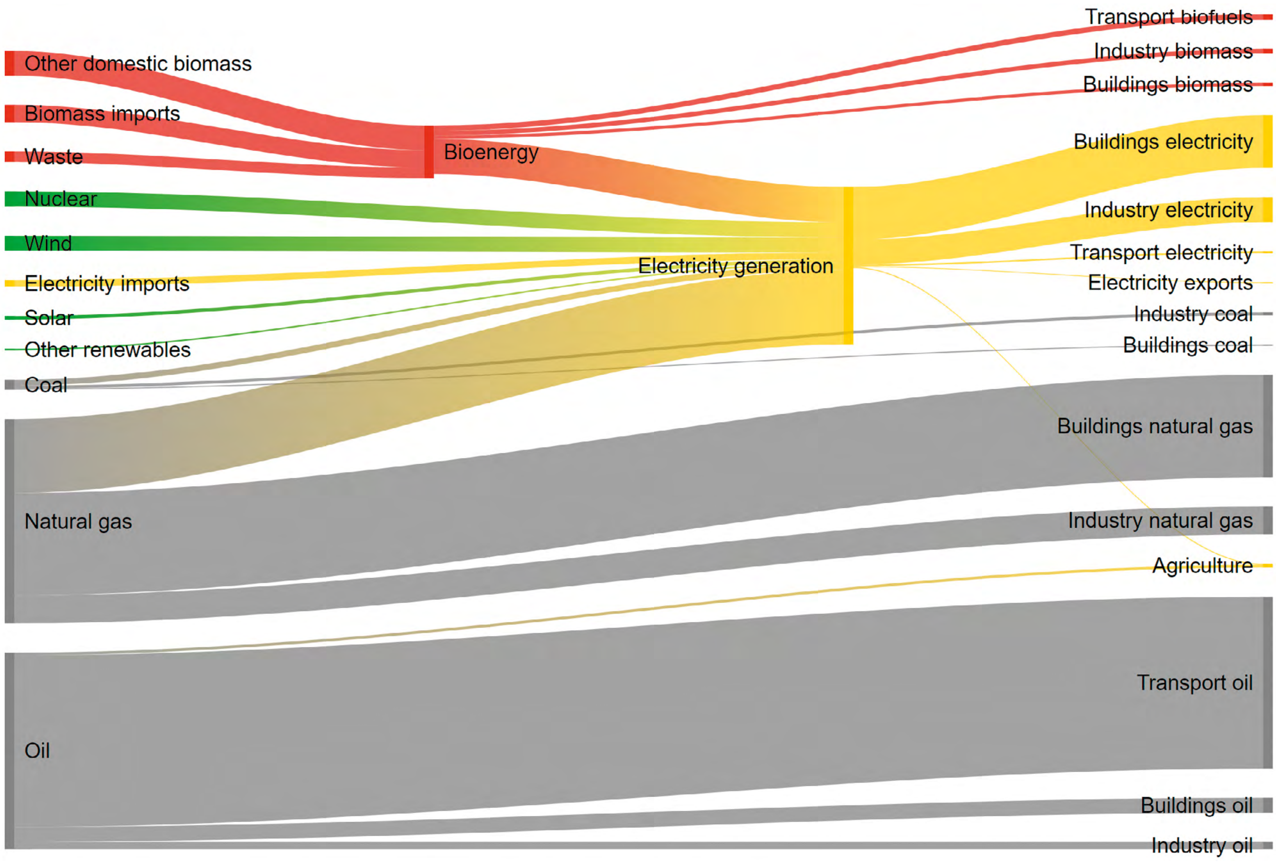
13. The exact technology and energy mix in 2050 cannot be known now, and our path to net zero will respond to the innovation and adoption of new technologies over time. We expect, however, to rely on the following key green technologies and energy carriers, which interact to meet demand across sectors and to remain low carbon.

- **Electricity** from low carbon generation and storage technologies meets higher demand for low carbon power in buildings, industry, transport, and agriculture;

- **Hydrogen** can complement the electricity system, especially in harder to electrify areas like parts of industry and heating, and in heavier transport such as aviation and shipping. A range of low carbon production methods could be used;[5]
- **Carbon capture usage and storage** (CCUS) can capture CO_2 from power generation, hydrogen production, and industrial processes – storing it underground or using it. This technology also supports negative emissions from engineered greenhouse gas removals – bioenergy with carbon capture and storage (BECCS) and Direct Air Carbon Capture and Storage (DACCS);
- **Biomass** combined with CCUS can remove carbon from the atmosphere and support low carbon electricity and hydrogen generation. Biomass and other wastes can also support low carbon fuels for industry, buildings, and transport.

14. These new technologies could transform our energy system by 2050. Electricity, low carbon hydrogen, and BECCS could all scale up, while reliance on fossil fuels will drop considerably and can be combined with carbon capture technology to abate emissions, with any residual emissions offset by greenhouse gas removals.

Figure 5: 2019 energy generation and end uses[6]



Illustrative 2050 scenarios

15. Modelling illustrative net zero scenarios allows us to explore possible energy and technology solutions in 2050, better understand important system-wide interactions, and identify features common to all options. Below we show three modelled scenarios all reaching net zero by 2050 through the same pace of decarbonisation, which demonstrate a range of practical ways in which net zero could feasibly be delivered with technology and resources known today.[7] They do not represent 'most likely' or 'preferred' solutions, and the actual position in 2050 may also vary outside of these scenarios. There is a great deal of uncertainty inherent in any modelling as far into the future as 2050, which is highly sensitive to economic, societal, and technological developments – see the *Technical Annex* for details of the modelling.

2050 Scenario 1: High electrification

Explores the impact of widespread electrification to support transport, heating, and industry decarbonisation, relative to other scenarios, with deep decarbonisation of electricity supply.

This pathway sees UK electricity generation increasing to around 690 TWh, more than doubling from today,[8] and low carbon hydrogen production scaling up to 240 TWh by 2050. Sectors such as road transport and buildings reach near zero emissions, through widespread electrification, with small residual emissions possible in personal and heavy goods transport; while the majority of buildings use electric heating, with the remainder using connected low carbon district heat networks. Industry emissions are near zero, through the full suite of green technologies (electricity, hydrogen, and CCUS), alongside energy efficiency measures. Electricity generation is overwhelmingly decarbonised, through widespread deployment of renewables alongside other low carbon generation including nuclear power and gas with CCUS. Residual emissions remain in aviation, agriculture, and waste, though these reduce from today's levels through, for example, sustainable aviation fuels, more efficient farm practices, and reduction in landfill waste. These emissions are balanced by significant afforestation, together with engineered removals (primarily BECCS but also DACCS).[9]

Figure 6: High electrification scenario: energy generation and end uses in 2050

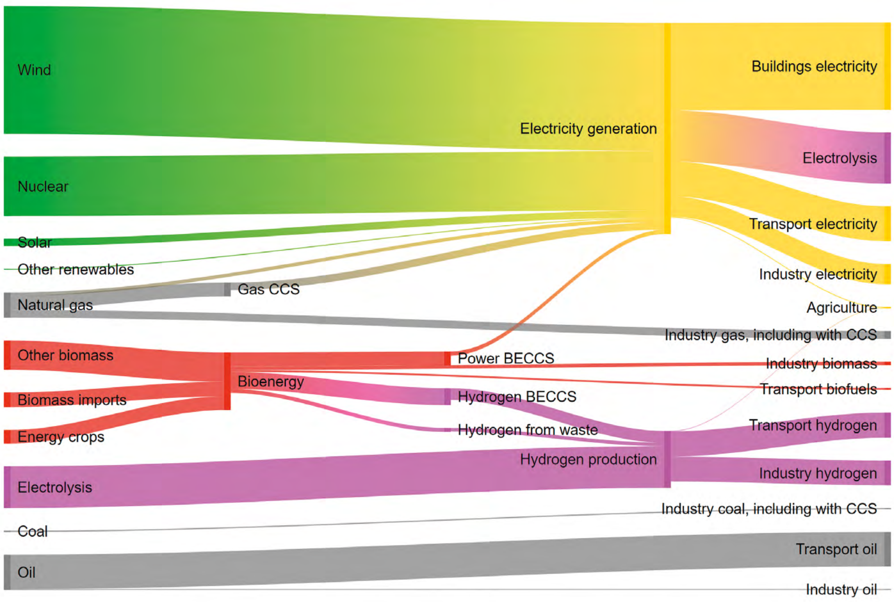
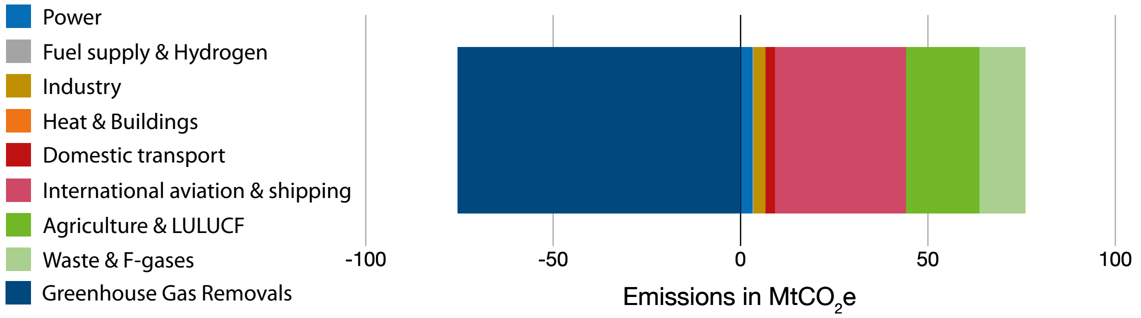


Figure 7: High electrification scenario: residual emissions in 2050



2050 Scenario 2: High resource

Explores the impact of using low carbon hydrogen more extensively, particularly for decarbonising buildings, power, and heavy vehicles. It also assumes higher levels of tree-planting are achievable, increasing the 'negative emissions' available from land-use sinks.

This pathway sees low carbon hydrogen generation increasing to around 500 TWh. As hydrogen is the main energy source for heating, electricity demand and therefore generation is lower than in scenario 1 at 610 TWh. Electricity and district heat still play a role in both residential and non-domestic buildings but the majority of building heat demand is assumed to be met by hydrogen. End users of energy (e.g. transport and buildings) reach similar levels of decarbonisation as in scenario 1. In heavy transport, there is a shift to increased use of hydrogen. Compared to scenario 1, greater levels of tree planting allow for slightly higher residual emissions to remain, primarily in hydrogen production. Engineered removals are at a similar scale to scenario 1 to offset remaining residual emissions in the hardest-to-decarbonise sectors of aviation and agriculture.

Figure 8: High resource scenario: energy generation and end uses in 2050

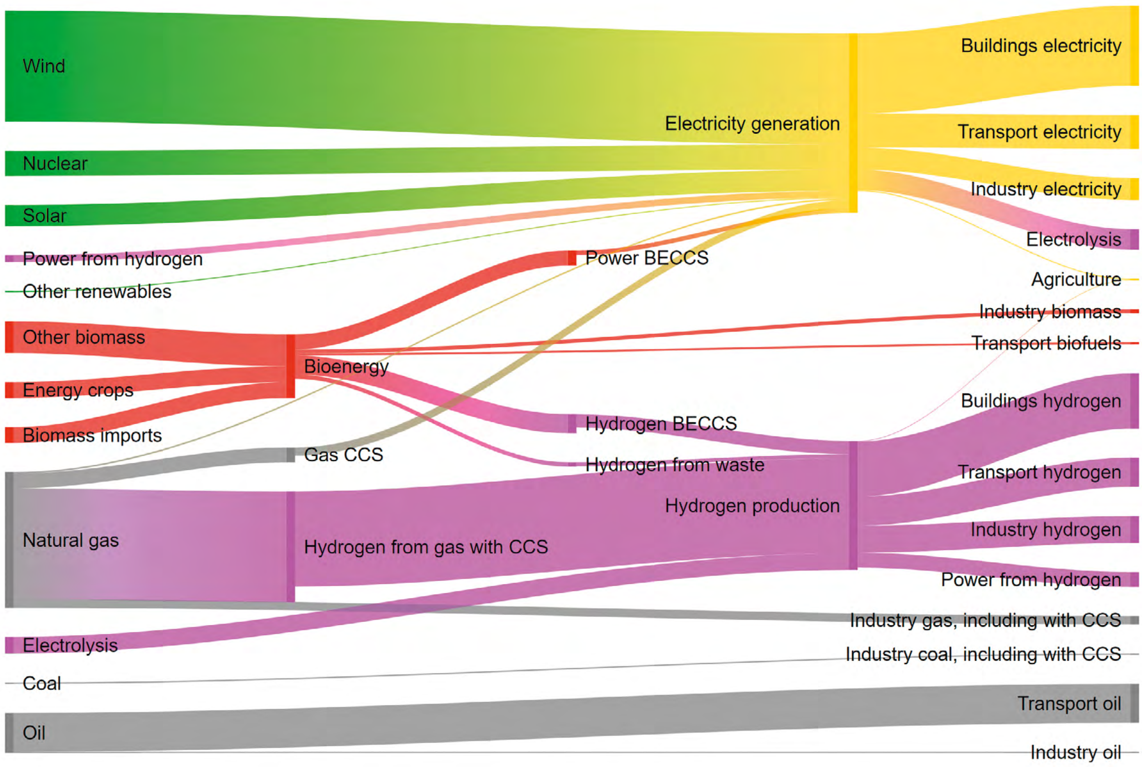
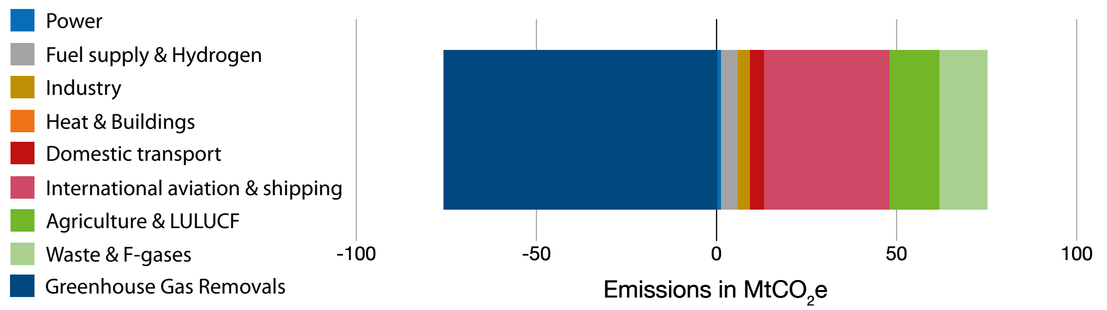


Figure 9: High resource scenario: residual emissions in 2050



2050 Scenario 3: High innovation

Explores a world in which successful innovations enable lower residual emissions to be reached in aviation, while higher capture rates increase the impact of carbon capture technologies, with higher levels of DACCS deployed over the 2040s.

In scenarios 1 and 2, end users of energy such as transport, industry, and buildings are decarbonised extensively, while accounting for residual emissions in aviation and baseline assumptions on the technological potential for carbon capture. In this scenario more optimistic assumptions around carbon capture and aviation, such as the availability of sustainable fuels at scale and zero emission aircraft, cause a divergence from scenarios 1 and 2 in the deployment of certain technologies. With lower residual emissions in aviation and improvement in capture or negative emission potential, end use sectors such as transport, buildings, agriculture and industrial dispersed sites can decarbonise to a lesser extent. This pathway sees electricity and low carbon hydrogen generation requirements in between the two scenarios explored previously, at 670 TWh and 330 TWh respectively.

Figure 10: High innovation scenario: energy generation and end uses in 2050

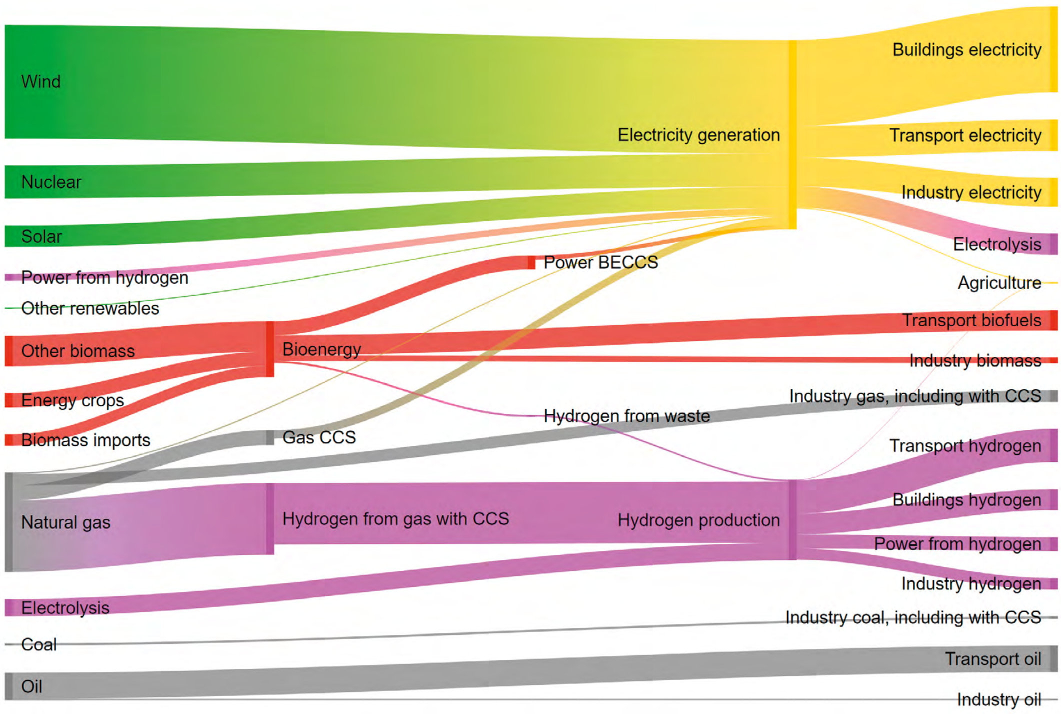
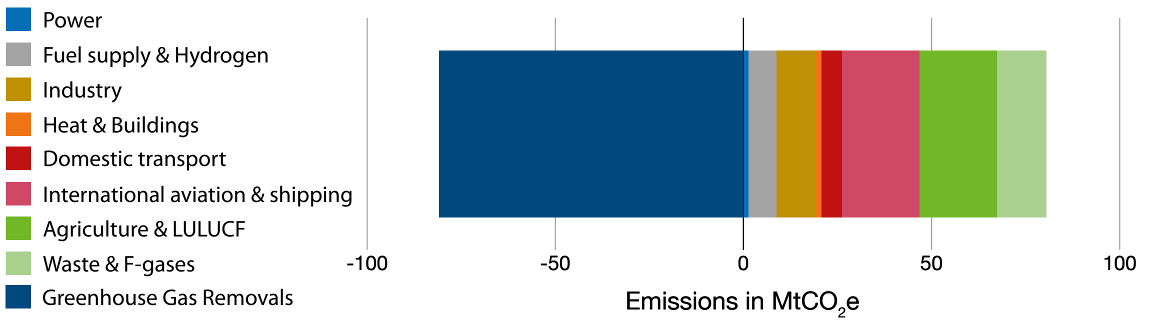


Figure 11: High innovation scenario: residual emissions in 2050



Insights from potential 2050 outcomes for net zero journey

16. Despite the uncertainties, we can draw some broad conclusions from the illustrative scenarios above to help shape our approach to net zero:

- Extensive decarbonisation is required across transport, buildings, and industry, given the need to account for possible residual emissions in agriculture, aviation, waste, and heavy industry and possible limitations on deployment of greenhouse gas removals;
- Given this, extensive energy efficiency measures across these sectors are likely to be beneficial to bring down energy demand and cost across the system. Every scenario sees overall energy demand from end use sectors reduce substantially;
- Different technologies for these sectors can be accommodated (for example, predominantly electric heat pumps or hydrogen for heating), meaning wide ranges of possible electricity and hydrogen demand remain plausible;
- Both electricity and hydrogen demand grow significantly from today, and need to be produced with very low levels of emissions by 2050. Biomass also becomes a key energy carrier to enable engineered removals and support low carbon fuel production;
- Given the need to plan for some residual emissions, it is appropriate to plan for use of greenhouse gas removals. The carbon capture processes needed for this are likely to play a significant role in wider decarbonisation, for example in power;
- Primary energy sources increase in number and diversify, including a range of renewables, and from biomass and waste. This diversified system for energy generation also becomes more interdependent to ensure security of supply.

Indicative delivery pathway to 2037

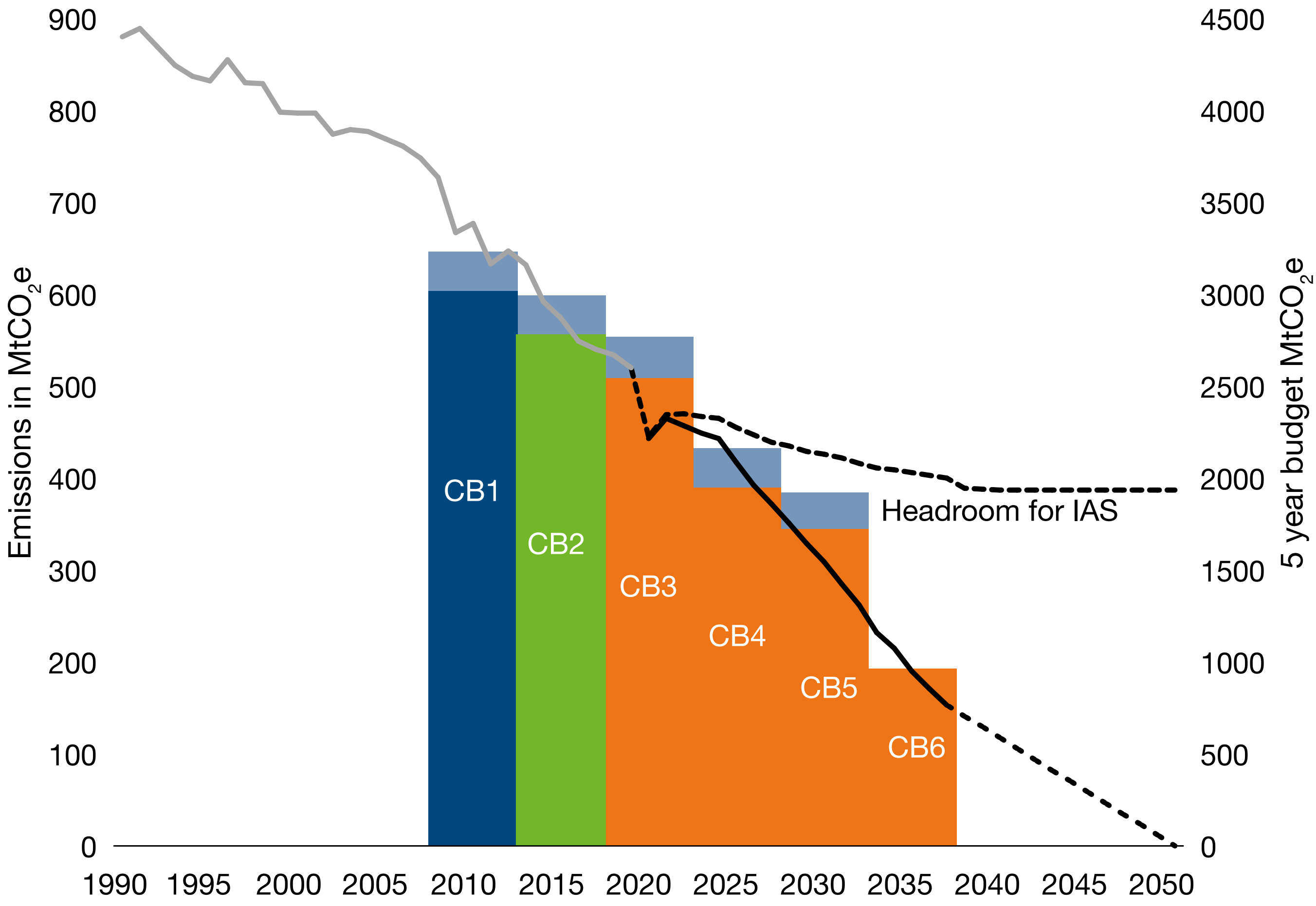
An indicative pathway meeting our emissions targets up to Carbon Budget 6

17. Drawing on the insights from our illustrative 2050 scenarios, we have developed a delivery pathway: an indicative trajectory of emissions reductions which meets our targets up to the sixth carbon budget ending in 2037. This is broadly consistent with all three 2050 scenarios and follows decarbonisation that we aim to achieve through this Strategy. The uncertainties inherent in our 2050 scenarios also apply to our 2037 delivery pathway. It is designed only to provide an indicative basis on which to make policy and plan to deliver on our whole-economy emissions targets. The exact path we take is likely to differ and must respond flexibly to changes that arise over time.

18. The pathway is based on our understanding now of the potential for each sector to reduce emissions up to 2037, considering the balance between sectors that is optimal for the entire economy in terms of delivery and cost. Emission reductions beyond our existing policies combine evidence on theoretical potential for abatement with judgements about barriers to delivery, the rate at which low carbon options could be adopted in practice and timescales for key decisions. We take an economy-wide view, including to balance end use sector demands with supply side considerations, such as infrastructure and the operation of the electricity and other fuel supply sectors.

19. As a general principle, our indicative pathway to 2037 prioritises emissions reductions where known technologies and solutions exist and thereby minimises reliance on the use of greenhouse gas removals to meet our targets. It is designed to drive progress in the short-term, while creating options in a way that seeks to keep the range of options presented in the illustrative 2050 scenarios open. The *Embedding Net Zero in Government* chapter sets out how Government will monitor progress to ensure we stay on track for our emissions targets and respond to developments affecting our long-term goals.

Figure 12: Indicative emissions reductions to meet UK carbon budgets and NDC[10]



2025 – 55% reduction (excluding international aviation and shipping emissions)

2030 – NDC target for at least 68% reduction (excluding international aviation and shipping)

2035 – 78% reduction (including international aviation and shipping)

2050 – 100% reduction

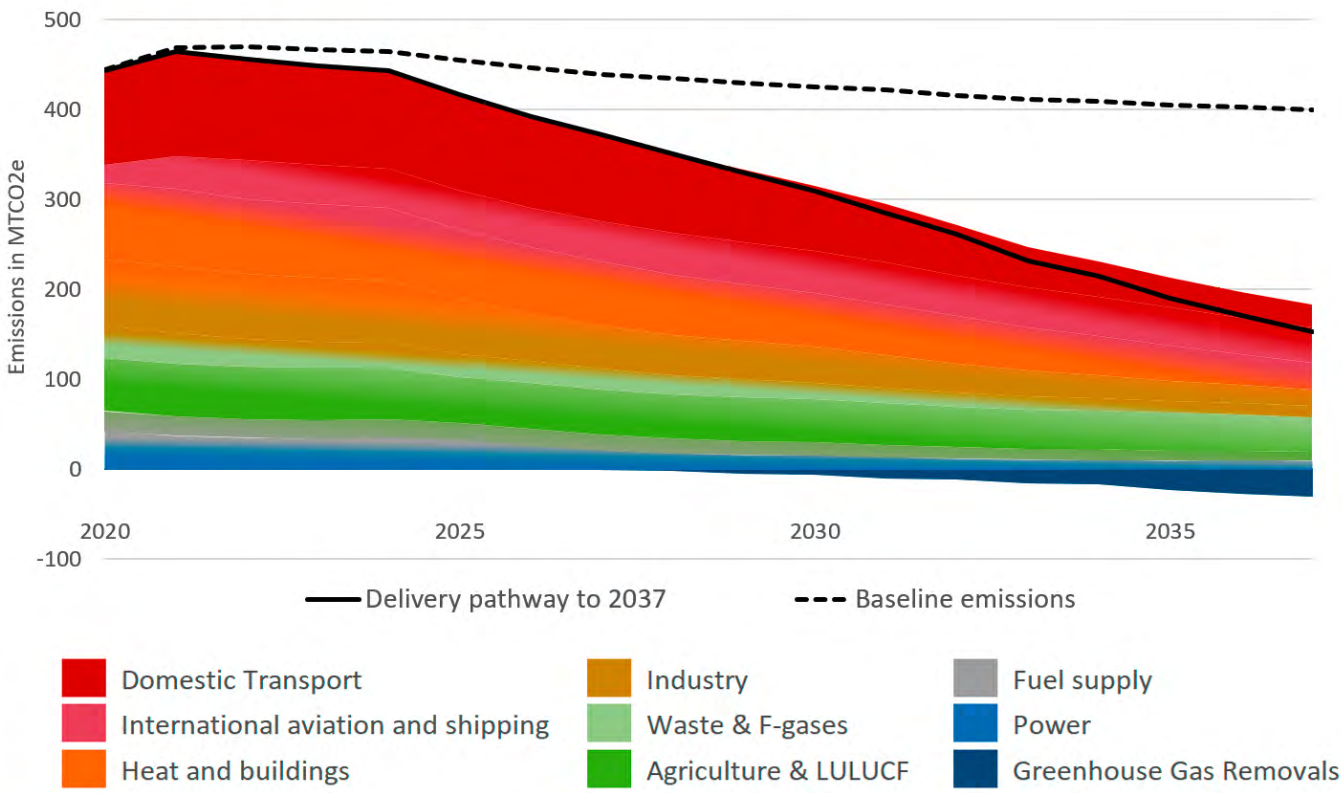
To meet whole-economy net zero target

Indicative sectoral decarbonisation pathways

20. Broken down by sector, our indicative delivery pathway implies the reduction in emissions up to 2037. These indicative sector pathways, presented as ranges for residual emissions to reflect the inherent uncertainty, help to drive change and to plan how we can remain on track to meet our targets.

Given the interdependencies and interactions within and between sectors, the exact areas for emissions savings may shift, as our understanding increases. These pathways are therefore not predictions or targets: the emissions savings ultimately contributed by each sector are likely to differ as we respond to real-world changes.

Figure 13: Indicative delivery pathway to 2037 by sector



Source: BEIS analysis

21. The pathway considers that sectors have the potential to make progress at different rates, for example, depending on the availability and deployment of technological solutions; development of supply chains, financing, and infrastructure; and the need to overcome wider delivery barriers. These constraints and action to overcome them are summarised below and explored in more detail in subsequent chapters.

Sector	% of UK emissions (2019)[11]	Expected reduction by 2035 from 1990	Key features of the delivery pathway to 2037
Power	11%	80-85%	By 2035, all our electricity will need to come from low carbon sources, subject to security of supply, moving to a fully decarbonised power system whilst meeting a 40-60% increase in demand. Expected residual emissions will be limited to CCUS plants, unabated gas, and energy from waste. This means increased investment in the grid network, electricity storage solutions and flexible grid management, to ensure decarbonisation without risking security of supply.
Fuel supply and Hydrogen	5%	53-60%	Large potential from electrification of oil and gas installations and addressing venting and flaring in the existing fuel supply sectors where demand is expected to fall over time. Emissions savings in the incumbent fuel supply sector will be marginally offset by emissions expected from low carbon hydrogen and fuel production, which will enable significant emissions savings through fuel switching across a range of end use sectors. Hydrogen production is expected to establish in the 2020s before a significant ramp up in the early 2030s, using a range of production methods to meet demand.
Industry	15%	63-76%	Deep decarbonisation through resource and energy efficiency, fuel switching, and CCUS deployment are all required, starting with industrial clusters and major emitters, such as the steel sector. Decarbonisation of smaller and more dispersed sites will also be needed, placing demands on associated infrastructure.

Heat and Buildings	17%	47-62%	Addressing heat emissions will require a substantial increase in the uptake of low carbon heating up to 2035, when all new installations will be net zero compatible. In any heat pathway, improved energy efficiency – through investment in buildings fabrics and better product standards – will reduce overall energy use and costs. Advanced smart meters will inform consumers and businesses about their energy use, encouraging energy-saving behaviour.
Transport[12]	32%	47-59%	Road transport is transformed through increasing use of zero emission vehicles, driven in part by ending the sale of new petrol and diesel cars and vans by 2030 and supported by increasing the share of trips taken by cycling, walking, and public transport. Progress is expected to decarbonise aviation and shipping through efficiency improvements and the uptake of low carbon fuels. These will require international coordination.
Natural Resources	20%	39-51%	Increased afforestation and peat restoration contribute significantly, though with long lead-in times. By 2035, perennial energy crop and short rotation forestry can contribute significantly to carbon sequestration, with potential to support power, fuel supply, industry, and transport through BECCS and generation of biofuels. Waste emissions reduce with increased diversion of municipal biodegradable waste streams away from landfill, and potential savings from other parts of the sector, such as wastewater. Use and therefore emissions of F-gases continues to reduce in response to future control measures. Agriculture emissions are largely from livestock and nutrient management. The pathway assumes emissions will be reduced through improved and innovative farming practices.
Greenhouse Gas Removals	Not applicable		Deployment of BECCS and DACCS. Deployment dependent on development of UK CCUS infrastructure and the availability of suitable, sustainable, and low-cost biomass feedstocks.

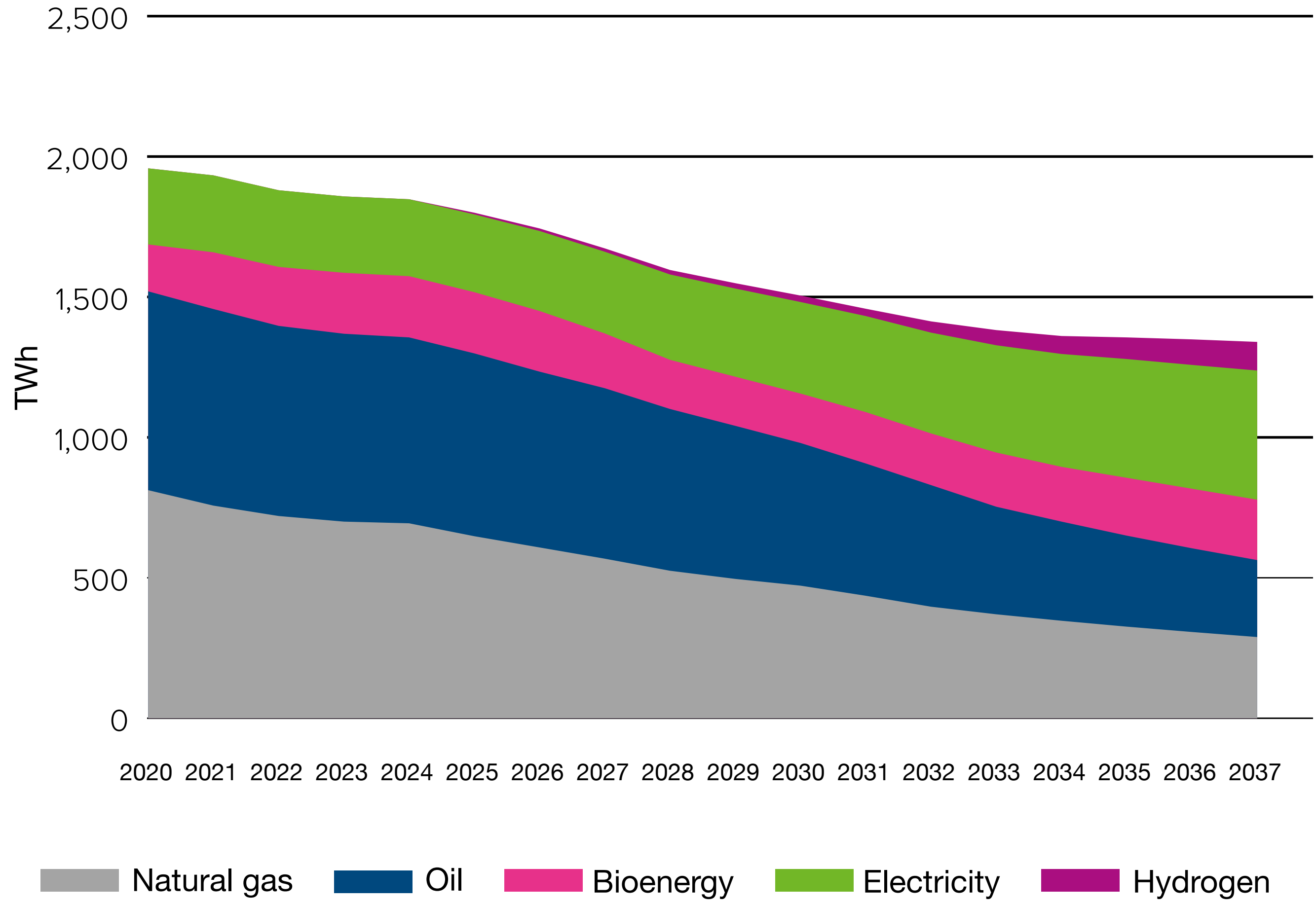
22. The changes we expect in sectors will evolve over time. In some cases, alternative measures within a sector could achieve broadly the same level of emissions abatement. In other cases, we will need to respond to strategic decisions that government makes in the future. One of the most significant decisions that will affect our pathway will be on the balance of types of low carbon heating solutions, mainly electricity and hydrogen, deployed in buildings. The *Heat and Buildings Strategy* commits to strategic decisions on the relative roles of hydrogen and electrification for on-grid homes by 2026 and the relevant sector chapter in this strategy explores alternative options that are consistent with the level of ambition implied by our delivery pathway.

Key energy changes and deployment implied by the delivery pathway

23. Assumed energy demand in our pathway is based on government's central assumptions about required technology uptake, with a variation to reflect the outstanding strategic decision on the potential role of hydrogen to heat buildings. We expect both natural gas and oil demand to more than halve by 2037 while overall, energy demand reduces significantly through increased efficiency and fossil fuels are replaced by new sources of energy. Electricity generation increases to meet a larger share of energy demand, and low carbon hydrogen grows from a near zero base to play a significant role from the 2030s.

24. Decisions in 2026 around hydrogen's role in providing heat in buildings will have a substantial impact on relative hydrogen and electricity demands – Figure 14 shows a scenario where hydrogen is not used to heat buildings, which is predominantly decarbonised via electrification through heat pumps. In a scenario where hydrogen has a more significant role in decarbonising heat in buildings, hydrogen demand would increase by 70 TWh by 2035 and electricity demand would decrease by 20 TWh (due to the high efficiency of heat pumps more hydrogen is required to produce the same amount of heat). Beyond heat, the indicative delivery pathway describes just one scenario for potential hydrogen demand in industry, transport, and power – the *UK Hydrogen Strategy* takes a wider view to consider greater ranges for hydrogen use in all sectors.[13]

Figure 14: Energy demands up to 2037 assumed by delivery pathway



Source: BEIS analysis

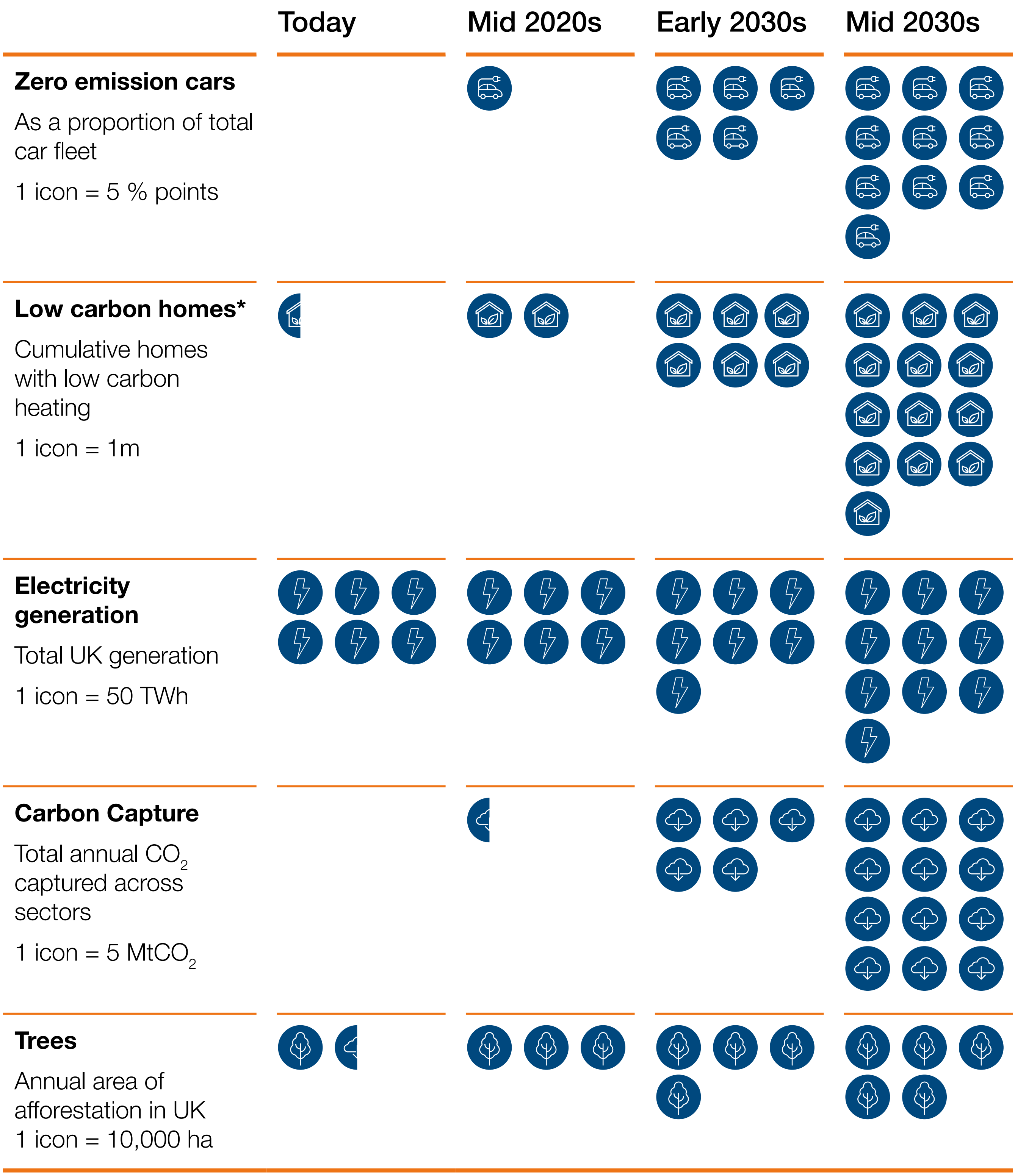
Note: for illustrative purposes, this shows energy demands in a scenario in which electricity is predominantly used to heat buildings. See the Technical Annex for hydrogen for heat scenario.

25. Meeting the increasing demand for low carbon energy across the economy relies on scaling up significantly, the new green technologies and energy carriers identified above. While the deployment of these will respond to changes over time, our indicative pathway suggests they are central to decarbonisation over the next 15 years:

- **Electricity** sees an expected 40-60% increase in demand by 2035, all met from low carbon sources to bring forward the government's commitment to a fully decarbonised power system by 15 years, subject to security of supply;
- **Hydrogen** production capacity ambition for 5 GW by 2030, which is expected to increase to around 10 or 17 GW by 2035 (depending on the role of hydrogen for heat);
- **Carbon capture** is expected to need to reach capacity for a total of ~20-30 $MtCO_2$ per year by the early 2030s across the economy – more than double what was set out in the *Ten Point Plan* – and at least ~50 $MtCO_2$ by the mid-2030s;
- **Biomass** is anticipated to need increases in feedstock supply from the 2020s to support BECCS deployment through various routes for use in 'hard-to-decarbonise' areas. These resources will be explored in the *Biomass Strategy.*

26. Figure 15 below shows some wider illustrative deployment of technologies or measures assumed in our pathway to demonstrate a sense of the scale and pace of change required. These are based on modelling assumptions, which are detailed in the *Technical Annex*, and do not represent targets – the delivery of such measures will depend on, and respond to, real-world change.

Figure 15: Illustrative examples of deployment implied by the delivery pathway



Note: For illustrative purposes, icons represent approximate and rounded figures from our modelling. Where there are ranges, an approximate central point has been shown.
** Homes with low carbon heating includes homes heated by heat pumps, hydrogen or connected to heat networks*

Essential activity driving the delivery pathway

27. It is, of course, impossible to predict every possible path to net zero that might arise over the next 30 years – we do not seek to do so. New innovations may emerge, enabling the market to move more quickly or at lower cost than expected, while in other areas progress may be hindered by unexpected deployment challenges as technologies are brought to scale. This Strategy does not attempt to ignore these uncertainties, but rather to plot a path which maintains flexibility in the future, while ensuring we do not delay the action we know is needed in the near-term. This aims to provide the certainty to drive forward investment and change, while allowing the market to respond to new opportunities and challenges which arise from the transition. The UK Emissions Trading Scheme is a crucial way in which we ensure that our pathway is rooted in cost-effective, market-led solutions.

UK Emissions Trading Scheme as a key driver of our path to net zero

The UK ETS, a 'cap and trade' scheme, is a market-based pricing mechanism to incentivise and control the reduction of emissions in a cost-effective way. A cap is set on the total amount of certain greenhouse gases that can be emitted by the sectors covered by the scheme over a given period. The cap is divided into allowances, and participants receive or purchase allowances which they can sell and buy with one another as needed. This UK ETS cap will reduce over time, providing a long-term market signal so companies can plan and invest in abatement accordingly – offering new trade and export opportunities. The cap is initially set 5% below the UK's notional share of the EU ETS cap for Phase IV of the EU ETS. We will consult in the coming months on an appropriate cap consistent with net zero.

The UK ETS acts as a cross-cutting policy lever to drive market-based abatement, incentivising industries to find the most cost-effective solutions to decarbonise. This ensures that, as industries develop lower carbon processes, our path to net zero adapts to cost-effective abatement routed in market-based solutions. We have committed to exploring expanding the UK ETS to the two thirds of uncovered emissions and we will provide a further update in due course. It remains important, however, that we develop policies which actively support and encourage sectors to decarbonise, rather than rely on applying an emissions cap and the consequent carbon pricing as our sole mechanism. Our delivery pathway provides a sound basis to underpin those policies to decarbonise, set out in the chapters that follow.

To mitigate the risk of carbon leakage, in which production and associated greenhouse gas emissions are offshored in ways that would not have happened if the pricing of emissions across jurisdictions was implemented in an equivalent way, we currently give at risk sectors a proportion of their allowances for free to reduce their exposure to the carbon price. We initiated a review of free allocation policy earlier this year with a call for evidence and plan to consult in the coming months, as part of a wider review into the UK ETS. This review will focus on how free allocations can be better targeted in line with a reduction to the overall cap, while still preserving the incentive to decarbonise.

28. Our analysis points to the following essential planks that we can be confident net zero will depend on. These underpin the chapters that follow in this Strategy.

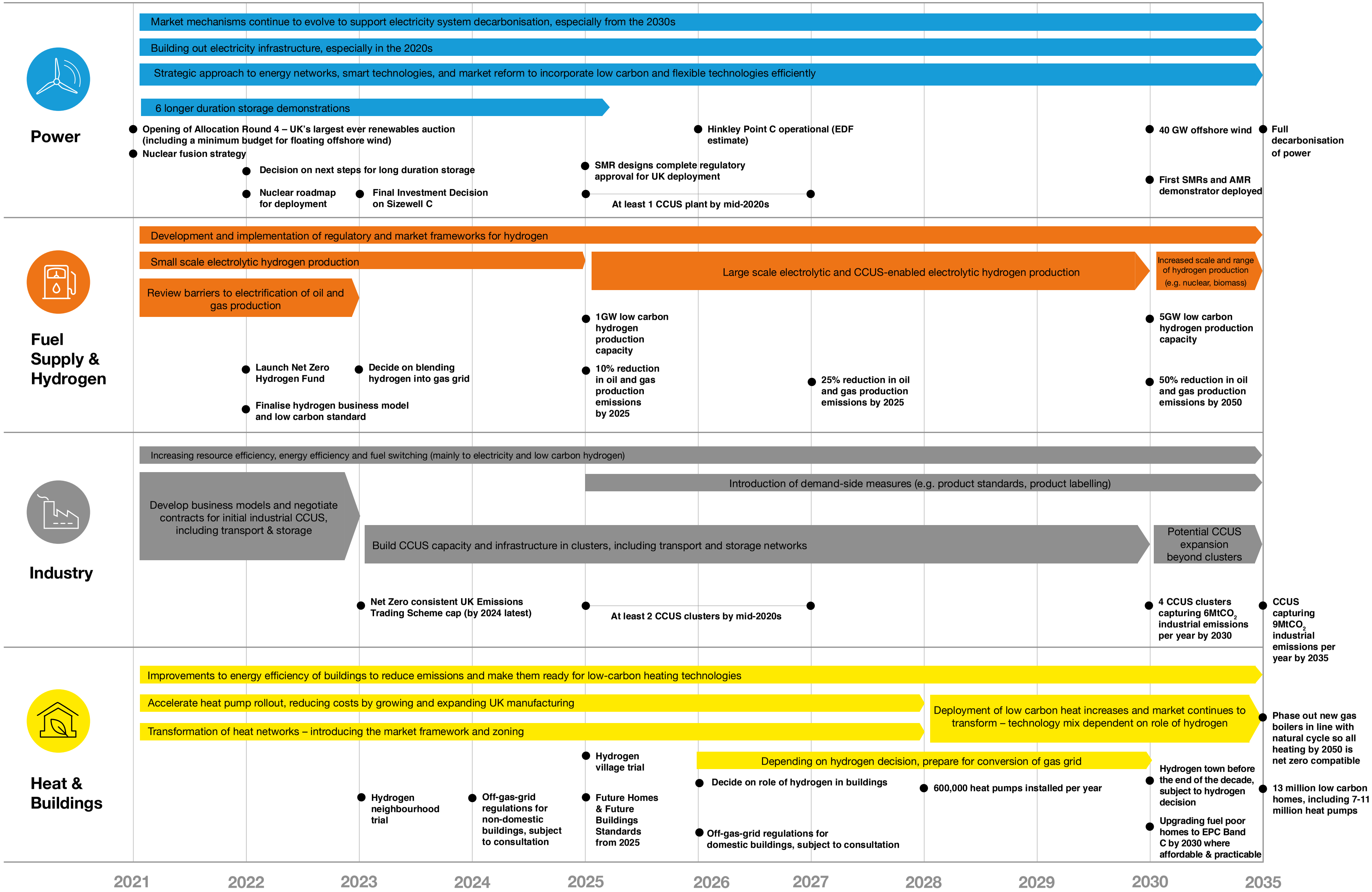
- **Integration of low carbon energy sources in a smart and flexible way.** For example, fully decarbonising our electricity system – in addition to renewables, nuclear, and power CCUS – could also rely on large-scale long duration storage, as well as use of BECCS and hydrogen-fired generation, to manage peaks in demand. Hydrogen could require substantial electricity for production via electrolysis, but in turn could help improve the efficiency of a high-renewables electricity system by using excess supply during periods of high generation and low demand, as well as further energy storage.
- **Increasing diversity of energy sources for end uses.** The removal of unabated fossil fuels from the system which currently supply most of the energy requirements in end use sectors, such as transport and heating, has potential to lead to a greater range of technologies and energy carriers playing a part in future. This could create some resilience, though there may not always be scope for direct substitution.
- **Increasing energy efficiency.** The low carbon energy system depends on overall energy demands reducing significantly. This means all demand sectors becoming far more efficient, through adoption of new technologies, better energy management, and direct investment in energy efficiency measures. Such measures can be considered 'low regret' to pursue throughout the transition and will, in turn, affect the level of energy supply and carbon capture required in the system.
- **Innovation for new technologies.** Green technology, including research and development into new options, is a cornerstone of the net zero journey. As well as the supply-side technologies discussed above, this also means new technologies in end use sectors – for example, installing zero carbon heating and delivering zero emission surface transport, while transforming the way we use natural resources, farm our land, and manage our waste. Different types of public and private support are required to develop nascent technologies and deploy known ones at scale. Government has a role to play in a financing offer, investment signalling, and developing business models.
- **Green investment.** Private investment will provide most of the financing needed to commercialise early technologies and scale low carbon sectors. We need additional net zero investment to reach c. £50-60 billion/year in the late-2020s and 2030s. However, public finance and public finance institutions will provide much of the early investment, intervention, and signalling that will create the conditions for an acceleration of net zero investment. This will also generate significant financial savings if achieved and accompanied by effective policy, thereby lowering the cost of capital for investment.
- **Demand-side changes and public engagement.** The rollout of low carbon solutions relies on positive public reception and demand to adopt them. Consumers need to have access to the right technologies, understand their benefits, and have confidence that they will be protected if they use them. The deployment of technologies should also respond to their reception by consumers, and go with the grain on consumer behaviour and trends. We also need our workforce to have the skills to meet increasing demand, including in areas such as housing retrofit, heat pump installation, electric vehicle manufacturing, charge

point installation and forestry. More widely, low carbon and environmental practices will require people and businesses to make green choices, and government has a role to play in making these as easy, attractive, and accessible as possible. The net zero journey must be a joint one and will be affected by how engaged and supportive the public are.

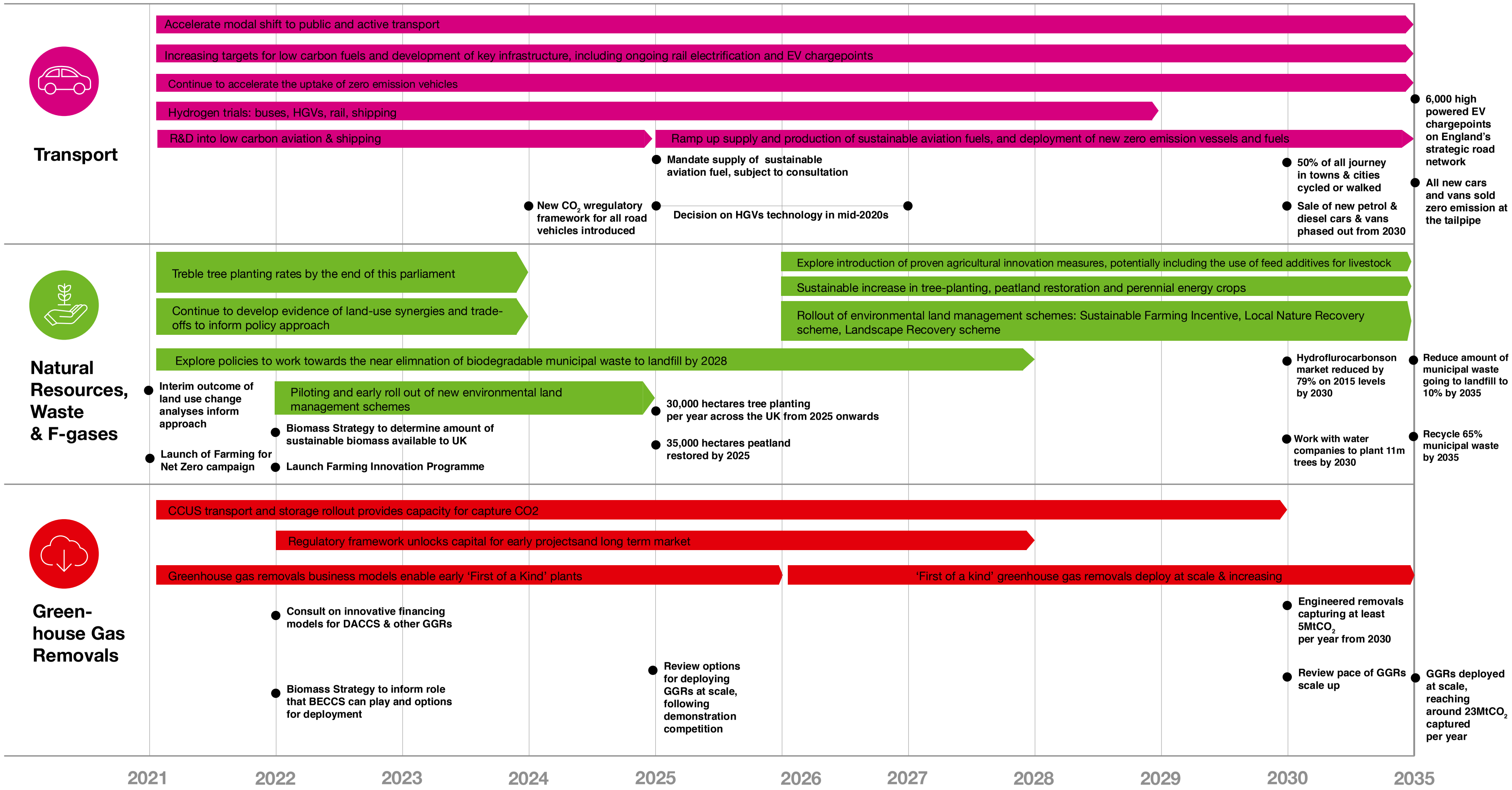
- **New standards and regulation.** In certain areas government will need to support and complement market-led decarbonisation with standards and regulation to ensure that, where appropriate, green options are pursued, while high carbon options are phased out. This will help to accelerate low regrets areas like energy efficiency, such as ensuring our homes are built to new standards, and high impact areas like zero emission vehicles. It will also ensure suppliers of higher-carbon technologies and fuels provide low carbon alternatives, driving deployment at scale.
- **Planning and infrastructure.** Low carbon solutions rely on transforming the infrastructure needed to deliver them. Increasing electricity generation needs to be accompanied by building out a flexible grid. Alongside dedicated hydrogen infrastructure, new CO_2 transport and storage infrastructure is needed for the use of CCUS which will require investment of around £15 billion from now to the end of the Carbon Budget 6 period. We need to ensure that low carbon energy generation can be connected to sources of demand geographically, which means improving knowledge of local circumstances and opportunities for generation. We also recognise the importance of the planning system to common challenges like combating climate change and supporting sustainable growth.
- **Sustainable use of resources.** Net zero will mean maximising the value of resources within a more efficient circular economy. It will need a significant increase in the use of certain types of resources – critical minerals like lithium, graphite, and cobalt, as well an increased demand on resources like copper and steel – from manufacturing green technologies to building large-scale infrastructure. This will require new robust supply chains and provide economic opportunities, but there will be environmental trade-offs, and potential negative impacts on habitats, biodiversity, and water resources to be managed carefully. For example, ammonia emissions from anaerobic digestion, which can use waste as a feedstock, can also affect biodiversity and health.
- **Understanding land use trade-offs.** Like other resources, our land is finite and competition for it will need to be managed as we rely on natural resources and use land for multiple new purposes, such as perennial energy crops and short rotation forestry for energy generation, while allowing for afforestation and peatland restoration to sequester and avoid emissions. We will also need to ensure net zero is compatible with wider uses of land such as agriculture, housing, infrastructure, and environmental goals. These land use challenges are exacerbated by the impact of climate change on the availability of productive land and water in future.

29. These features underpin the critical activity driving decarbonisation across sectors of the economy. A summary is provided below up to 2035, which is not exhaustive but focuses on the new technologies which need to be developed and deployed over the next decade. Policies and proposals to detail *how* this activity is achieved are set out in subsequent chapters.

Figure 16: high-level essential activity across sectors to 2035



Note: Markers indicate the year milestones will occur rather than the precise point in a given year, while arrows of activity are inclusive of the years in which they start and finish



Note: Markers indicate the year milestones will rather than the precise point in a given year, while arrows of activity are inclusive of the year they run to start and finish

Endnotes

[1] BEIS analysis (2021), 'Final UK greenhouse gas emission national statistics: 1990 to 2019', https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2019

[2] HM Treasury (2021), 'Net Zero Review: Final Report'.

[3] OBR (2021), 'Fiscal Risks Report', https://obr.uk/frr/fiscal-risks-report-july-2021/

[4] BEIS (2021), 'Impact Assessment for the sixth carbon budget', https://www.legislation.gov.uk/ukdsi/2021/9780348222616/impacts

[5] Production methods include: electrolysis, which splits water into hydrogen and oxygen using electricity; steam methane reformation with CCUS, which uses heat, steam, and catalysts to break methane (from natural gas) into hydrogen and carbon dioxide which is then stored underground; and biomass gasification with CCUS, where heating biomass in special conditions produces a mix of gases including hydrogen and carbon dioxide which is used or permanently stored.

[6] BEIS analysis based on 2019 data from the BEIS, *Digest of UK Energy Statistics*, https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes#2021

[7] These scenarios have been developed using whole system cost-optimisation modelling (UK TIMES) to produce a feasible range of least-cost solutions and deployment requirements for given emissions targets.

[8] Terrawatt-hour is a unit of energy equal to one trillion watts for one hour to indicate energy generation and demand.

[9] Emissions from Greenhouse Gas Removals only include engineered removals. Nature-based solutions, such as afforestation, are included in the Agriculture and LULUCF subsector. For further detail see the Natural Resources, Waste & F-Gases and Greenhouse Gas Removals chapters.

[10] Estimates of historical UK GHG emissions are revised annually to incorporate methodological improvements, updated data and changes to international guidelines. The percentage reductions implied by CB levels are therefore subject to change.

[11] BEIS analysis (2021), 'Final UK greenhouse gas emission national statistics: 1990 to 2019', https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2019

[12] Transport emissions include emissions from domestic transport and international aviation and shipping.

[13] BEIS (2021), 'UK Hydrogen Strategy', https://www.gov.uk/government/publications/uk-hydrogen-strategy