May 2025

Wales' Fourth Carbon Budget

Advice for the Welsh Government

Climate Change Committee

Wales' Fourth Carbon Budget

Climate Change Committee
14 May 2025

Presented to Welsh Ministers pursuant to Section 50 of the Environment (Wales) Act 2016. This report was published on 14 May 2025 and is available online at: www.theccc.org.uk/publications

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The Committee

The Climate Change Committee (CCC) is an independent, statutory body established under the Climate Change Act 2008. Our purpose is to advise the UK and devolved governments on emissions targets and to report to Parliament on progress made in reducing greenhouse gas emissions and preparing for and adapting to the impacts of climate change.

Members of the Committee include:

Professor Piers Forster, Interim Chair
Piers Forster is Director of the Priestley Centre for Climate Futures and Professor of Physical Climate Change at the University of Leeds. He has played a significant role authoring Intergovernmental Panel on Climate Change (IPCC) reports, and is a coordinating lead author role for the IPCC's sixth assessment report.

Professor Keith Bell
Keith Bell is a co-Director of the UK Energy Research Centre (UKERC), a Chartered Engineer and a Fellow of the Royal Society of Edinburgh. He has been at the University of Strathclyde since 2005, was appointed to the Scottish Power Chair in Smart Grids in 2013 and has been involved in energy system research in collaboration with many academic and industrial partners.

Dr Steven Fries
Steven Fries is a Senior Associate Fellow at the Institute for New Economic Thinking at the Oxford Martin School, University of Oxford, and Nonresident Senior Fellow at the Peterson Institute for International Economics. Steven has previously held roles as group chief economist at Shell and chief economist at the Department of Energy and Climate Change.

Professor Corrine Le Quéré FRS
Corinne Le Quéré is a Royal Society Research Professor at the University of East Anglia (UEA), specialising in the interactions between climate change and the carbon cycle. She was lead author of several assessment reports for the UN's Intergovernmental Panel on Climate Change (IPCC) and previously chaired the French Haut Conseil pour le Climat.

Professor Swenja Surminski
Swenja Surminski is Chair of the Munich Climate Insurance Initiative, Managing Director Climate and Sustainability at Marsh McLennan and Professor in Practice at the Grantham Research Institute at the London School of Economics (LSE). Her work focuses on capacity building and knowledge transfer between science, policy and industry, building on her work in industry and as advisor to governments, private sector and civil society, including as Visiting Academic at the Bank of England.

Nigel Topping CMG
Nigel Topping was appointed by the UK Prime Minister as UN Climate Change High Level Champion for COP26. In this role Nigel mobilised global private sector and local government to take bold action on climate change, launching the Race To Zero and Race To Resilience campaigns and, with Mark Carney, the Glasgow Financial Alliance for Net Zero.

Acknowledgements

The Committee would like to thank:

The team that prepared this report and its analysis. This was led by Emma Pinchbeck, James Richardson, Emily Nurse, Eoin Devane, James Tarlton, and Luke Jones and included Sasha Abraham, Rose Armitage, Florence Bates, Simona Battipaglia, Owen Bellamy, George Blake, Sandra Bogelein, Marili Boufounou, Marta Calore, Christian Calvillo Munoz, Rachel Carr-Whitworth, Lidice Cruz-Rodriguez, Selina Dagless, Bianca de Farias Letti, Victoria de la Cruz, Ramesh Deonarine, Joshua Deru, Tom Dooks, Caitlin Douglas, Kim Dowsett, Kieron Driscoll, Ahmed Gailani, Francesco Maria Giacomini, Ruth Gregg, Esther Harris, Cara Hawkins, Rachel Hay, Cilla Hellgren, Robbie Herring, Gemma Holmes, Daisy Jameson, Ariana Jessa, Sam Karslake, Emma Kearney, Miriam Kennedy, Michael Lord, Grace Macready, Luke Maxfield, Moryse McInniss, Aaron McMahon, Richard Millar, Bea Natzler, Chloe Nemo, Chris Parker, Finna Parkinson, Emma Patterson, Lois Player, Simon Rayner, Andrew Romang, Elena Saggioro, Miranda Schroder, Viv Scott, Penny Seera, Olivia Shears, Marcus Shepheard, Bryony Sheridan, Joris Simaitis, Thomas Smith, Rachael Steller, Felicity Taylor, Seán Taylor, Indra Thillainathan, Sam Van Stroud, Emma Vause, Sophie Vipond, Zelna Weich, Chloe Welsh, Eveline White, Hannah Williams, Kate Williamson, Louis Worthington, Charley Wright, Ken Wright, and Susie Wright.

Our previous Committee member, Professor Michael Davies.

Our expert advisor on the role of households and the public in the Net Zero transition, Professor Rebecca Willis.

A wide range of organisations and individuals who participated in workshops, engaged with us, submitted evidence, or met with the Committee bilaterally.

Executive summary

The climate is changing. Global warming has unequivocally been caused by greenhouse gas emissions, with 100% of the observed long-term temperature change attributable to human causes. Evidence of climate change is being seen in Wales. In 2022, Wales recorded its highest ever temperature of 37.1°C at Hawarden Airport, Flintshire, impacting health, ecosystems, and infrastructure.

The Environment (Wales) Act 2016 ('the Act') sets the framework for the Welsh Government to address climate change. The Act has an ambitious target to reach Net Zero greenhouse gas emissions by 2050, with any residual emissions balanced by removing carbon dioxide from the atmosphere. There are also decadal targets in 2030 and 2040 and five-yearly caps on emissions in Wales, known as carbon budgets, that started in 2016. The Committee is required to advise the Welsh Government on the level of these targets.

In this report, we outline our advice on the level of Wales' Fourth Carbon Budget. Our recommended level for the budget is a 73% reduction in average annual emissions compared to the 1990 baseline, over the five-year period from 2031 to 2035, including Wales' contribution to international aviation and shipping.

The start of Wales' Fourth Carbon Budget is only six years away. Achieving it will require a focus on key near-term actions, particularly in surface transport, buildings, and agriculture and land use. These sectors have significant policy powers devolved to the Welsh Government and achieving the Fourth Carbon Budget provides an opportunity for Wales to lead by example.

The growth of renewables and the take-up of electric vehicles (EVs) and heat pumps provide the majority of the emissions reduction required between now and the Fourth Carbon Budget period, along with better insulation in buildings. Clean, efficient, electric technologies will mean reduced air pollution and should mean lower energy bills than continued reliance on fossil fuel technologies.

The transition to an electric arc furnace at the Port Talbot steelworks will reduce emissions from industry, but there are important lessons to learn from the way in which the closure of the blast furnaces was managed. The challenges facing the UK steel sector have been clear for many years and, given the significance of this site to the local economy, a more proactive and decisive transition plan should have been developed for Port Talbot.

This transition plan could have included the UK and Welsh governments working together with local authorities to develop a local industrial strategy to support alternative employment, including in industries such as heating services and floating wind, ahead of the closure of the blast furnaces. Industry and government must learn lessons from the experience in Port Talbot to guide future efforts to decarbonise other strategically and locally significant emissions-intensive industries, for example oil refineries such as in Pembroke.

The Welsh Government will also need to support farmers and rural communities to diversify their incomes away from livestock farming and towards woodland creation and peatland restoration. In our pathway, agriculture and land use together reach Net Zero by 2050, as sequestration, mostly from tree-planting, offsets the continued emissions from livestock. Our analysis maintains the self-sufficiency ratio of UK food consumption met by UK production. Achieving this balance requires reductions in livestock numbers, both to reduce methane emissions and to free up land for woodland creation and peatland restoration. Emissions are also reduced through low-carbon farming practices, such as the use of feed additives to inhibit methane production in cattle. Farmers and land managers need to be enabled to adopt the right mix of measures for their land.

This will require incentives to diversify land use into woodland creation, peatland restoration, and renewable energy, combined with long-term certainty on public funding for low-carbon farming practices.

Across the Welsh economy, reducing dependency on fossil fuels will increase economic resilience against price shocks in volatile international fossil fuel markets. Investing in new technologies also offers wider economic opportunities: lower operational costs, especially for vehicles, and the chance to capture a share of growing markets for low-carbon goods and services.

We estimate that the net cost of Net Zero in Wales will be around 0.4% of GDP per year on average in our pathway. Much of this investment, in particular in electricity supply, EVs, and heat pumps, generates operational savings as inefficient fossil fuel technologies are replaced by more efficient electric alternatives. The majority of those investments will be private capital.

Improved air quality and other co-benefits of emissions reduction mean that the Committee's pathway for Wales supports objectives in other Welsh legislation, such as the goals in the Well-being of Future Generations (Wales) Act 2015. In line with the Environment (Wales) Act 2016, this advice also takes account of the most recent Future Trends Report and the Future Generations Report under the Well-being of Future Generations (Wales) Act (see Section 4.3) and the latest State of Natural Resources Report (see Section 4.4).

Our advice is based on the latest technological, social, and economic evidence; extensive sector modelling; and engagement with stakeholders. The Committee's advice also considers the relationship of UK-wide action on climate change to specific features of the Welsh economy and devolved powers – for example, the relative importance of agriculture or industry. While the Committee offers advice, decisions on the exact pathway and policies to meet any targets are for the Welsh Government and the Senedd.

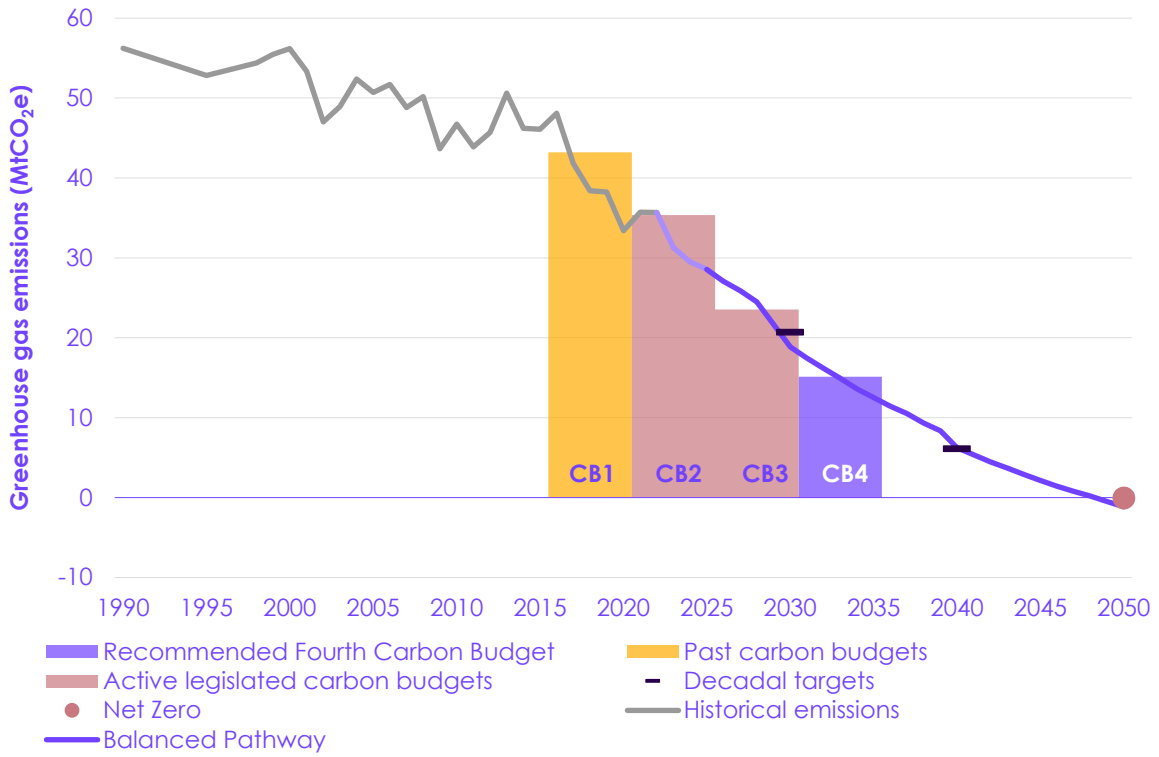
The Balanced Pathway and the Fourth Carbon Budget

In 2022, emissions in Wales were 35.7 $MtCO_2e$, 37% lower than levels in 1990. Since the Act was legislated, the pace of emissions reduction has increased, with over half this reduction having occurred since 2016. Wales has achieved its First Carbon Budget and is now part way through its Second (Figure 1).

Our advice on the level of the Fourth Carbon Budget, covering the period from 2031 to 2035, is based on our Balanced Pathway for Wales: a modelled emissions reduction pathway from 2025 to Net Zero by 2050. The pathway meets the legislated decadal targets for 2030 and 2040 and the Second and Third Carbon Budgets, which cover the period up to 2030.

In our pathway, emissions over the Fourth Carbon Budget period are projected to be an annual average of 73% lower than levels in 1990 and 58% lower than levels in 2022. This requires a continuation of the pace of emissions reduction seen since 2016.

Figure 1 The recommended Fourth Carbon Budget

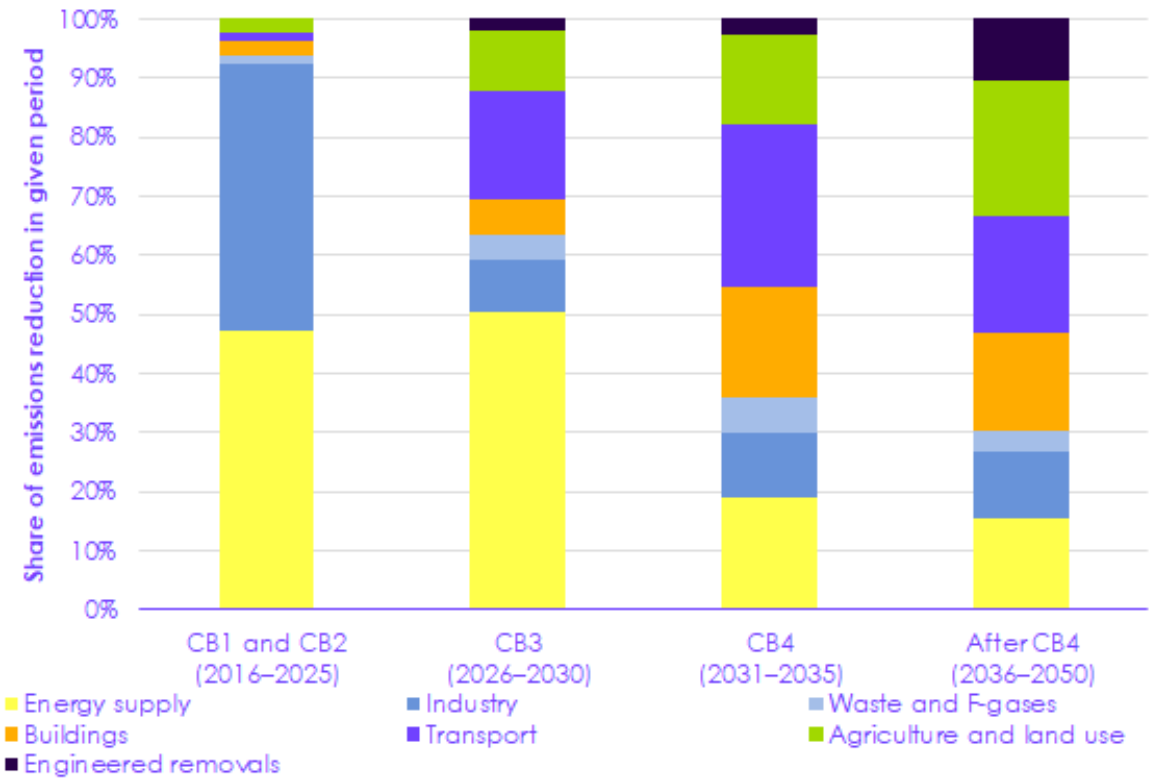


Description: The Committee recommends that the Fourth Carbon Budget should be set at an average annual reduction of 73% below the 1990 baseline for the period 2031–2035.
Source: National Atmospheric Emissions Inventory (2024) *Greenhouse Gas Inventories for England, Scotland, Wales & Northern Ireland: 1990-2022*; CCC analysis.
Notes: See Chapter 2. 'CB' refers to Wales' carbon budgets: 'CB1' refers to the First Carbon Budget; subsequent numbers refer to subsequent carbon budgets.

More than 90% of the emissions reductions over the first two carbon budgets are from the energy supply and industry sectors (Figure 2). The phase-out of coal and the ramp-up of renewable electricity generation has led to a significant fall in electricity supply emissions since 2016. In 2022, industry was Wales' highest emitting sector, but the closure of the blast furnaces at the Port Talbot steelworks last year means emissions from industry will now have more than halved since then.

Decarbonising electricity supply provides around half the emissions reduction required over the Third Carbon Budget period (2026 to 2030). But contributions from surface transport, agriculture and land use, and buildings become increasingly important, together comprising more than 60% of the emissions reduction required over the Fourth Carbon Budget period (Figure 2).

Figure 2 Distribution of emissions reductions during each carbon budget period in the Balanced Pathway for Wales



Description: Action to reduce emissions is needed across a wide range of sectors. While the vast majority of emissions reductions during the first two carbon budgets have come in the energy supply and industry sectors, increasing contributions from surface transport, agriculture and land use, and buildings will be required to meet the next two carbon budgets.
Source: Department for Energy Security and Net Zero (DESNZ) (2024) *Final UK greenhouse gas emissions national statistics: 1990 to 2022*; National Atmospheric Emissions Inventory (2024) *Greenhouse Gas Inventories for England, Scotland, Wales & Northern Ireland: 1990-2022*; CCC analysis.
Notes: See Chapter 3. 'CB' refers to Wales' carbon budgets: 'CB1' refers to the First Carbon Budget; subsequent numbers refer to subsequent carbon budgets.

Sources of future emissions reduction

Around two-thirds of the reduction in emissions required to meet the Fourth Carbon Budget in our pathway is delivered by electrification of key technologies in transport, buildings, and industry, together with the expansion and decarbonisation of the electricity system. There are also important contributions from demand reduction, low-carbon fuels, and low-carbon farming. Going beyond the Fourth Carbon Budget, emissions reductions from nature-based measures and engineered removals become increasingly important (Figure 3).

1. Electricity

Clean electricity replaces oil and gas in surface transport, buildings, and much of industry. This transition is well under way by the Fourth Carbon Budget period, providing around two-thirds (67%) of the required emissions reduction. Ending the combustion of oil and gas in boilers and cars will lead to cleaner air and a healthier Wales, one of the key goals under the Well-being of Future Generations (Wales) Act 2015.

- **Low-carbon supply:** in our pathway, capacity of variable renewables (a combination of offshore and onshore wind and solar) more than doubles to 8.0 GW by 2033. This provides 78% of electricity generation and caters for increasing demand in Wales as well as the rest of Great Britain. The remaining electricity generation largely comes from flexible dispatchable sources (17%). This is mostly low-carbon, either gas with carbon capture and storage (CCS) or hydrogen-fired turbines, with a small strategic supply of unabated gas. Firm power sources which are predictable and schedulable but relatively inflexible make up 5% of generation. Dispatchable and firm power, together with grid storage, ensures a reliable supply of electricity even in adverse weather years. These technologies need to be accompanied by rapidly expanding the transmission grid, upgrading the distribution network, and speeding up the grid connection process.

- **EVs:** by 2033, around one-third of cars and vans and one-sixth of heavy goods vehicles on the roads in Wales are fully electric in our pathway, compared to 1.2% for cars and 0.6% for vans in 2023. This requires a rapid increase in the market share of new electric cars and vans, reaching 90% by 2030, from 8% and 2% respectively for cars and vans in 2023. This transition will be underpinned by the falling costs of batteries in EVs, with new electric cars and vans expected to reach price parity with petrol and diesel vehicles between 2026 and 2028.

- **Heat pumps:** by 2033, nearly a quarter of existing homes in Wales are heated by low-carbon electrified heating, predominately heat pumps, in our pathway. Annual installation rates will need to accelerate rapidly, reaching nearly 25,000 in 2030, a rate of increase in line with that seen in other European countries, such as the Republic of Ireland and the Netherlands. But installation rates do not exceed natural replacement cycles: heating systems are only replaced at the end of their life in our pathway.

- **Industrial electrification:** electric alternatives, including the electric arc furnace at the Port Talbot steelworks, replace most types of fossil fuel-fired industrial equipment. Electrifying industry allows manufacturers in Wales to benefit from global demand for low-carbon goods.

2. Low-carbon farming, low-carbon fuels, and CCS

While electrification is the main technological decarbonisation solution in key sectors, there is also an important supporting role for low-carbon fuels and CCS. This contribution is small during the Fourth Carbon Budget period, but scales up in later years. Agriculture is both an important industry and significant source of emissions in Wales, so developing low-carbon farming practices is essential. Together, these make up 10% of the reduction in emissions required to meet the Fourth Carbon Budget in our pathway, a significant share of which comes from low-carbon farming.

- **Low-carbon farming:** a number of low-carbon farming practices and technologies are introduced in our pathway, providing around half the emissions reduction in the agriculture sector. Livestock dominates the sector in Wales, with feed additives and waste and manure management being the most important measures.

- **Low-carbon fuels:** ships transition to a mix of low-carbon fuels, predominantly low-carbon ammonia and synthetic fuels. Planes transition to using some sustainable aviation fuels. Hydrogen plays a small but important role in industry and in larger off-road mobile vehicles in agriculture, as well as a possible role in low-carbon dispatchable electricity generation. However, we see no role for hydrogen in heating for buildings.

- **CCS:** as well as in low-carbon dispatchable electricity generation, CCS plays an important role in industry, for example capturing process emissions from cement production. It is also used for low-carbon hydrogen production, at Wales' two energy from waste plants, and to underpin engineered removals in our pathway.

3. Demand

Measures to reduce the demand for high-carbon goods and services are particularly important to reduce emissions while technologies are still transitioning. In 2033, around two-thirds of cars and three-quarters of home heating in Wales will still be powered by fossil fuels, so reducing demand and improving efficiency presents a significant opportunity to decrease emissions. These measures contribute 21% of the reduction in emissions required to meet the Fourth Carbon Budget in our pathway for Wales.

- **Increased efficiency:** by 2033, our pathway sees cost-effective resource and/or energy efficiency measures deployed across most sectors. This includes home insulation, more efficient use of resources in industry, and reductions in commercial, household, and food waste. Wales has a strong record on recycling and should aim to go beyond UK-wide reforms to deliver on its ambitious goals.

- **Low-carbon choices:** by 2033, our pathway sees people make some shifts towards lower-carbon choices, including a shift to public transport and active travel, and a reduction in meat (especially beef and lamb) and dairy consumption across the UK, within overall healthier diets. Flying remains close to today's levels until technology develops.

4. Nature

Nature-based measures, including restoring peatlands and planting new woodland, are integral in growing land-based carbon sequestration. Together with renewables, they provide opportunities for Welsh farmers and land managers to diversify their income streams away from livestock farming.

Nature-based measures are vital for Wales to achieve its longer-term targets. There is a delay between the planting of woodlands and the time it takes for them to reach peak sequestration rates. New woodlands planted post 2025 become a net sink in the early 2040s. Scaling up these nature-based actions allows agriculture and land use together to reach Net Zero emissions by 2050.

These measures require changes in use for 14% of Wales' land, in line with the equivalent for the UK as a whole. However, because of variations in land types and infrastructure constraints in utilising energy crops, there is a greater emphasis on woodland creation within Wales.

- **Woodland and agroforestry:** the proportion of woodland cover rises from the current 15% to 17% in 2033 and 26% by 2050, allowing diverse woodlands to deliver carbon sequestration. Delivering this will require a significant increase in planting rates over the next decade, which must be supported by addressing barriers and incentivising land managers and farmers. Trees and hedges on farms also play a role, supporting continued food production alongside sequestration in vegetation and soils.

- **Peatlands:** rewetting and restoration of degraded peatlands offers further emissions reduction and improves the resilience of ecosystems across Wales. Our pathway sees a rise in the proportion of peatland under such management from the current 41% to 52% by 2033.

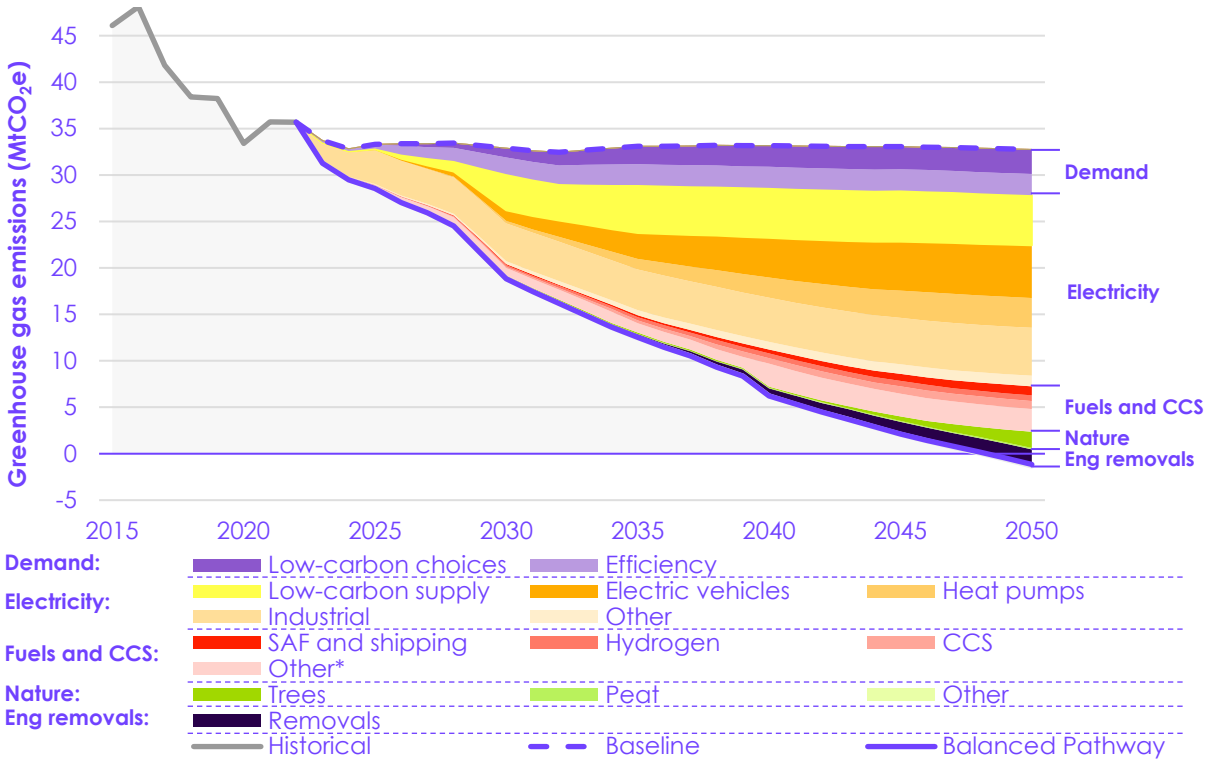
5. Engineered removals

Engineered removals help to balance residual emissions from sectors that cannot fully decarbonise in 2050. With emissions from agriculture balanced by land use sinks in our pathway, engineered removals are used to balance small residual emissions, especially in industry and waste.

Our pathway sees a gradual ramp-up in engineered removals starting during the Third Carbon Budget period and reaching -1.8 $MtCO_2e$ by 2050. It is predominantly a mix of direct air carbon capture and storage (DACCS) and bioenergy with carbon capture and storage (BECCS), with smaller contributions from enhanced weathering and biochar.

The amount of engineered removals in 2050 is driven by the need for the UK as a whole to balance residual emissions to achieve Net Zero, with Wales' share of engineered removals technologies based on locational assumptions in our pathway.

Figure 3 Sources of abatement in the Balanced Pathway



Description: The Fourth Carbon Budget is delivered through five key routes: electricity, low-carbon fuels and CCS, nature, engineered removals, and demand. The largest share of emissions reduction is from the switch from fossil fuels to electric technologies powered using low-carbon electricity.
Source: CCC analysis.
Notes: See Chapter 2. *The other category within low-carbon fuels and CCS includes low-carbon farming practices, such as the use of methane-suppressing feed additives. 'Eng removals' refers to engineered removals. 'SAF' refers to sustainable aviation fuel. 'CCS' refers to carbon capture and storage.

The cost of the transition

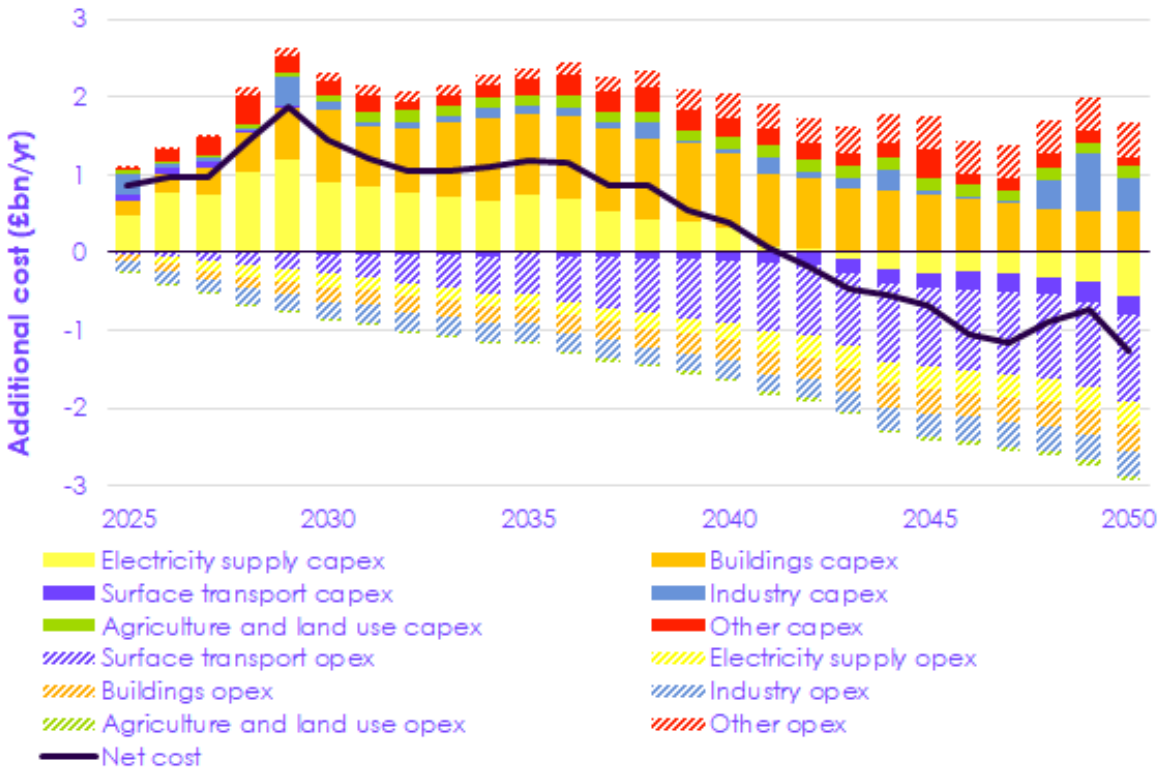
The Balanced Pathway requires upfront investment. In many sectors, this upfront investment will lead to significant savings in the future as inefficient fossil fuel technologies are replaced by more efficient, low-carbon alternatives. When combining capital and operating costs, we expect the Balanced Pathway to result in a net saving during the early 2040s. On average there will be a net cost of around £390 million per year between 2025 and 2050, which is around 0.4% of GDP (Figure 4).

- EVs will lead to a significant cost saving. Electric cars and vans are already generally cheaper to run and maintain, and will soon be cheaper to buy, than their fossil fuel-based alternatives. Households will see a significant reduction in the cost of driving.

- Heat pumps are more efficient than gas boilers, which should lead to lower household energy bills. However, homes in Wales are predominantly designed around gas heating and will need a one-off improvement to be suitable for heat pumps in many cases.

- Electricity supply requires upfront investment in renewable generation and grid infrastructure. With much lower operating costs, they generate savings over time in our pathway.

Figure 4 Additional costs and savings in the Balanced Pathway



Description: Additional costs in the Balanced Pathway are front-loaded, peaking in 2029. Capital costs are offset by operating savings in later years, with the pathway becoming a net cost saving overall in 2042.
Source: CCC analysis.
Notes: See Chapter 2. 'Capex' is additional capital expenditure and 'opex' is additional operating expenditure. Both are relative to a baseline of no further decarbonisation action.

Households and the economy

So far, emissions reductions in Wales have largely involved actions by business and government. To meet the Fourth Carbon Budget, households will need to make some changes. The most important will be to buy heat pumps and electric cars, when it is time to replace fossil fuel boilers or cars; to eat less meat and dairy, building on current dietary trends; and to keep flying close to today's levels until technology develops. Policy and business action will need to make household low-carbon choices easy, attractive, and affordable, and ensure trusted information is provided to the public.

Households in Wales, including those in less energy efficient houses or in fuel poverty (14% of Welsh households in 2021), will benefit from more efficient technologies, lower bills, less draughty homes, and cleaner air. This helps promote a healthier Wales.

The transition will also reduce Wales' dependence on international fossil fuel markets, making the economy more resilient. Beyond this, most sectors of the economy, particularly in services, will see little change in activity other than switching to low-carbon heating and vehicles. Transitioning to a low-carbon economy can safeguard and enhance Wales' natural resources, promote the Welsh regenerative economy, and provide a stepping stone for improving ecosystem resilience.

Energy-intensive manufacturing, a relatively important part of the Welsh economy, will face additional costs to eliminate emissions. Government should ensure the right incentives are in place for these sectors to switch to low-carbon production, ensuring they are ready to take advantage of growing markets for low-carbon goods and services. Government should work closely with workers, unions, communities, and businesses to put in place funded transition plans that ensure attractive employment opportunities.

The Welsh Government also needs to engage with farmers and their communities, and support them to diversify their incomes, including towards woodland creation and peatland restoration, keeping in mind implications for Welsh heritage and culture. UK-wide policy must protect against risks of carbon leakage from agricultural imports. In the Balanced Pathway, a reduction in demand for meat and dairy in the UK avoids imports of these products increasing. Carbon border adjustment mechanisms may also be needed.

Key actions

We have 16 priority recommendations for immediate action to put Wales on track to deliver the Fourth Carbon Budget. The full set can be found in Annex 1. Core themes include:

- **Supporting households to install low-carbon heating.** Wales needs to rapidly transition to low-carbon electrified heat. While the Net Zero transition should lead to lower energy bills for consumers, support is needed to address barriers in upfront costs, especially for low-income households. It is also important to support households, particularly those on low incomes, to install home insulation measures. These can reduce emissions before heating systems are replaced, reduce bills, and provide more comfortable homes.

- **Expanding EV charging and travel infrastructure.** Support the deployment of public charge points across Wales. The number of public EV charge points per capita in Wales is similar to the UK average, but will need to continue to increase in line with EV uptake. With prices for new and second-hand EVs falling, there is an opportunity for rapid take-up provided the right infrastructure is in place and people are provided with accessible, accurate information on their benefits. Wales should also invest to improve public and active travel infrastructure.

- **Farming and nature.** Long-term certainty is needed on public funding for farming practices and technologies to reduce emissions from managing crops and livestock, and incentives and markets should be provided for farmers and land managers to diversify their incomes for actions including woodland creation, peatland restoration, and renewable energy.

- **Engagement.** The Welsh Government should work with the UK Government to develop and implement an engagement strategy to provide clear, trusted information about the most effective actions for households and businesses in Wales to reduce emissions and the benefits of low-carbon choices, signposting to available sources of advice and support.

- **Jobs.** The Welsh Government should publish a Net Zero skills action plan to identify and address barriers to enable growth of the workforces needed to deliver the Net Zero transition. The Welsh Government should work with businesses and communities that may be affected by the Net Zero transition to develop proactive transition plans that enable access to secure employment and business opportunities.

Next steps

The Committee provides advice but does not set policy. Decisions remain with the Welsh Government and the Senedd. The Welsh Government should now propose a level for the Fourth Carbon Budget to the Senedd. This must be set by the end of 2025.

Above all, to meet our Fourth Carbon Budget pathway, immediate action is necessary. We are already approaching the end of the Second Carbon Budget and action needs to accelerate and broaden to more sectors. Action by government, businesses, and households can drive a rapid shift away from fossil fuels, boost investment, and support good new jobs.

Chapter 1: Introduction

Introduction and key messages

This report sets out the Committee's advice to the Welsh Government on the level of the Fourth Carbon Budget, covering the period 2031 to 2035, as required by the Environment (Wales) Act 2016 (hereafter 'the Act'). Our advice is based on analysis underpinning our advice to the UK on the level of the UK's Seventh Carbon Budget. That advice report contains more detail on the analysis.

This chapter summarises the latest scientific knowledge about climate change, sets out Wales' current targets under the Act, and summarises current emissions trends in Wales.

Our key messages are:

- The Earth's climate is changing rapidly as human-induced warming is increasing at an unprecedented rate. Risks are increasing - extreme weather events show the impact that climate change is already having, globally, in the UK, and in Wales. Every 0.1°C of additional warming creates increasing threats from climate change.

- The science is clear that human activities have driven increases in greenhouse gases (GHGs) in the atmosphere to levels not previously experienced by our species. Long-term human-induced warming now reaches around 1.3°C above pre-industrial levels and is rising at over 0.2°C per decade.

- Net Zero CO_2 emissions as well as deep reductions in other GHG emissions globally are required to halt further global warming. While it is now almost inevitable that warming levels will exceed 1.5°C in the next ten years, it may still be possible to limit warming close to 1.5°C in the longer term, provided deep global emissions cuts begin immediately.

- Global action must speed up. The UN Framework Convention on Climate Change (UNFCCC) process, the Paris Agreement, government policies, action from non-state actors, and market initiatives are driving progress. Global GHG emissions are likely near their peak, and on a per capita basis have begun to fall. But much more action is needed.

- Emissions in Wales have decreased by 37% since 1990, and the First Carbon Budget (2016 to 2020) was achieved. Emissions are now dominated by agriculture, electricity supply, and surface transport.

1.1 The latest scientific knowledge about climate change

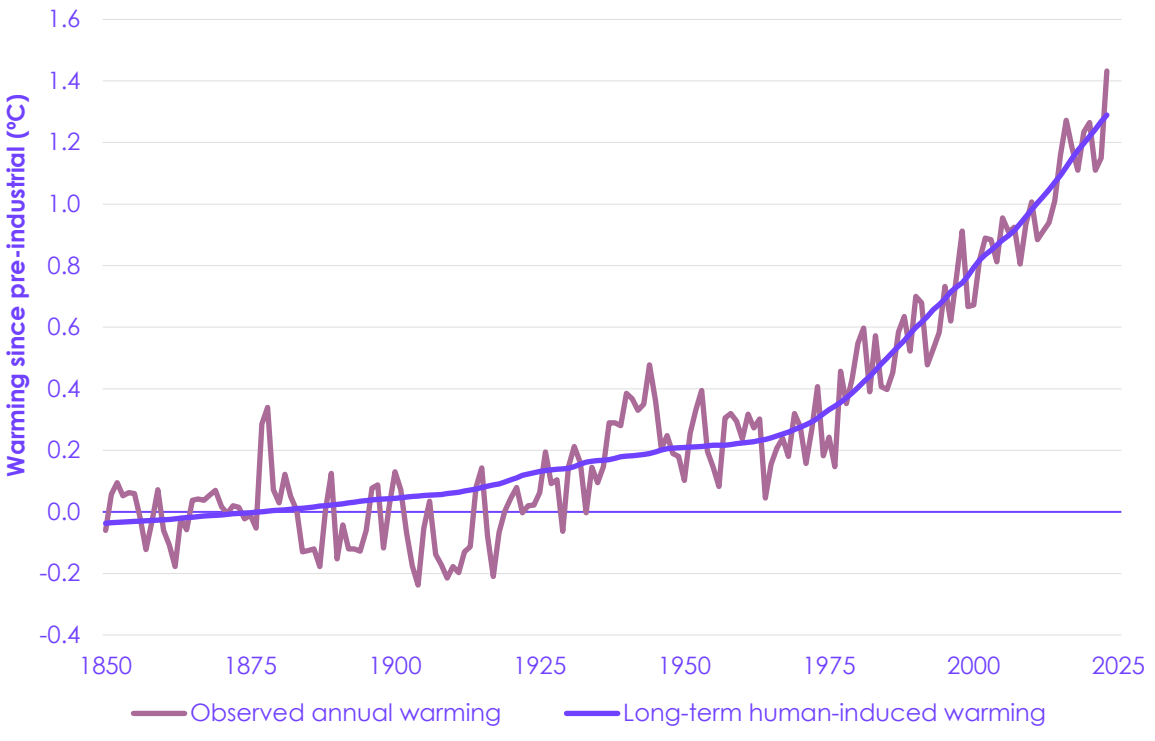
Global temperatures are rising (Figure 1.1). Since 2020, climate and weather records have continued to be broken around the world.

- Global temperatures have continued to increase. 2024 was the warmest year on record, at 1.6°C above pre-industrial average levels.[1] Long-term human-induced global warming in 2023 is estimated to have risen to 1.3°C (1.1°C to 1.7°C, 5th to 95th percentile range) above pre-industrial average levels.[*] The rate of increase is unprecedented, reaching 0.26°C per decade over 2014 to 2023.[†;2]

- Records for climate and weather extremes continue to be broken. In 2023, ocean heat content reached its highest level in the 65-year observational record and global mean sea level reached a record high. Extreme weather events, such as wildfires and flooding, led to widespread loss of life and property destruction.[3]

- Warming will inevitably continue in the near term. Global temperatures will continue to rise until the point when the world reaches Net Zero CO_2 emissions, with deep reductions in other GHGs also needed to limit warming.[4] This continued warming means that the world is rapidly approaching the lower end of the Paris Agreement long-term temperature goal (Box 1.1).

Figure 1.1 Global average temperature rise



Description: Since 1850, global average temperatures have been increasing, with a particular acceleration beginning around 1970. Observed annual temperatures fluctuate around long-term human-induced warming.
Source: Smith, C. et al (2024) *Climate indicator data: indicators of global climate change 2023 revision.*
Notes: (1) Observed annual warming shown reflects an average across several datasets. (2) Long-term human-induced uses the 'anthropogenic p50' metric from Smith, C. et al (2024).

[*] These estimates are based on the IPCC's Sixth Assessment Report methodology. Long-term warming refers to the average level of warming over a multi-decadal period, as distinct from the warming observed in a single year (such as that referred to for 2024).

[†] At the time of writing, long-term warming trends have not yet been updated to include 2024 warming data.

Box 1.1
Global warming of 1.5ºC

Long-term warming

The 2015 Paris Agreement has a single long-term temperature goal: 'holding the increase in the global average temperature to well below 2ºC above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5ºC above pre-industrial levels'. While not formally defined in the Agreement itself, the warming levels referenced in this goal are widely interpreted as referring to multi-decadal human-induced average warming, excluding short-term natural variability.[5] For simplicity, this is often referred to as 'long-term warming'.

Since 2015, advancing climate science has further highlighted risks of exceeding 1.5ºC of long-term warming. The UNFCCC Conference of the Parties (COP) has recognised these risks and put a greater focus on pursuing efforts to keep to 1.5ºC above pre-industrial levels - such as in the agreed conclusions on the first Global Stocktake under the Paris Agreement which concluded in 2023.

Long-term global warming, as measured according to this interpretation, has not yet exceeded 1.5ºC above pre-industrial levels, but it is rapidly approaching it. Estimates of current human-induced long-term warming are around 1.31ºC above pre-industrial levels and are rising at 0.26ºC per decade.[6]

Short-term variability

The Earth's temperature also experiences short-term fluctuations on both annual and monthly timescales which can temporarily increase or lower global temperatures from the human-induced long-term average. A major contributor to this is the El Niño cycle - which occurs in the Pacific but has a large impact on global temperature. The large and persistent El Niño occurring over late 2023 and 2024 was one of the reasons that global average temperature anomalies have repeatedly, but temporarily, reached 1.5ºC or higher above pre-industrial levels. February 2023 to January 2024 was the first 12-month period where the mean global average temperature exceeded 1.5ºC above pre-industrial levels, and June 2024 marked the twelfth consecutive month to reach or surpass 1.5ºC warming.[7] 2024 was the warmest calendar year on record, surpassing 1.5ºC warming for the first time.[8]

This does not mean that the long-term temperature goal of the Paris Agreement has been breached; limiting long-term warming to 1.5ºC remains a central goal in the UNFCCC process.

Looking ahead

While it is theoretically possible to return long-term warming to below 1.5ºC following a limited overshoot, every increment of global warming brings additional risks, both in terms of climate impacts and to the chances of bringing warming back down over time.[*]

- In nearly all of the modelled scenarios considered by the Intergovernmental Panel on Climate Change (IPCC), long-term warming exceeds 1.5ºC above pre-industrial levels in the early 2030s. Some degree of exceedance is therefore now almost inevitable.
- Under current policies, the remaining global carbon budget for 1.5ºC would be exhausted by 2030. By the 2030s, global warming will likely be at or above 1.5ºC even in a global highest ambition scenario.[9]
- Recent analyses suggest it is still technically possible to limit long-term warming to 1.5ºC with low overshoot. Deep and immediate emissions cuts are required, and the required rate of global emissions reduction increases with every year global action falls short of that implied by 1.5ºC-aligned pathways.[10;11]
- Long-term warming above 1.5ºC, even temporarily, will bring additional impacts that will need to be adapted to. The greater the overshoot, the larger the climate risks associated with the warming during and after the overshoot period, including the risk of crossing tipping points.[†;12]
- A greater degree of overshoot also implies a larger need for CO_2 removal measures and net negative emissions to bring temperatures back down. Many of these measures are not yet proven at scale and have uncertain costs and large implications for energy systems.[13]

[*] 'Overshoot' refers to the temporary exceedance of a given level of warming, after which temperatures fall back to below that level.

[†] A 'tipping point' refers to a critical threshold in the Earth's system or related processes which, if passed, can cause sudden, dramatic, or even irreversible changes to some of the Earth's largest systems.

1.1.2 Global emissions

There is a near-linear relationship between cumulative anthropogenic CO_2 emissions and the global warming they cause. Continued emissions of CO_2 and other long-lived GHGs therefore imply continued warming.[14]

Global GHG emissions grew steeply throughout the second half of the 20th century and have continued to grow over recent years, albeit at a slowing rate.

- Annual net global CO_2 emissions from fossil fuels and land use, land use change, and forestry (land use) in 2023 were around 41 $GtCO_2$.[15] This makes 2023 emissions approximately joint highest in the modern record, with 2019.
  - Global emissions of methane contributed around one-third of the total GHG-driven global warming seen by 2010 to 2019.[16] Recent estimates show methane emissions continue to rise, implying a growing contribution to warming, and in 2023 were 2–4% above 2019 levels.[17;18]
- The rate of increase has slowed over the past decade. The rate of growth in global fossil CO_2 emissions peaked at nearly 3% per year during the 2000s but has slowed in the last decade to less than 1% per year on average.[19]
  - Global GHG emissions per capita (excluding emissions from land use, for which uncertainty is larger) broadly plateaued in the 2010s and in 2023 were 1% below peak levels, which occurred in 2012.[20;21]
- Various sources expect global emissions to peak this decade.
  - The International Energy Agency and Bloomberg New Energy Finance both project an immediate or mid-2020s peak for energy sector CO_2 emissions under current policy settings.[22;23]
  - The UNFCCC assesses that if countries implement their 2030 emissions targets in full, global GHG emissions will peak in the 2020s.[24]

1.1.3 Latest scientific understanding

The Intergovernmental Panel on Climate Change (IPCC) completed its Sixth Assessment Report (AR6) cycle in 2023. This brings together the last five years of scientific studies and provides the scientific basis for this report. It concluded that human activities have 'unequivocally caused global warming', and that limiting human-induced global warming to 1.5°C requires deep, rapid, and sustained reductions in GHG emissions.

- Global temperatures are increasing as a result of human activities. The increase in average global surface temperatures has been driven by increases in GHG concentrations, which have unequivocally been caused by GHG emissions from fossil fuels and other human activities.
- Human-caused climate change is already affecting weather extremes across the globe. Evidence has strengthened linking human influence to observed changes in extremes such as heatwaves, heavy rainfall, droughts, and tropical storms. Human influence has also likely increased the chance of these events occurring simultaneously. Vulnerable communities are disproportionately affected by these extreme events.

- Risks increase as warming increases. Changes in extreme climate events become larger with every additional increment of warming. Concurrent extreme weather and sea level events are projected to become more frequent, storms to become more intense, and arid conditions to become more widespread. Abrupt and irreversible changes, including those triggered when tipping points are reached, become more likely and more impactful with further warming. For any given level of warming, many climate-related risks are assessed to be higher than in the IPCC's previous assessments.

- Limiting human-caused warming requires deep and immediate emissions cuts. Modelled IPCC pathways that limit warming to 1.5°C (with low or no overshoot) reach global Net Zero CO_2 in the early 2050s. These pathways see global GHG emissions peak by 2025 and assume deep and immediate cuts in emissions are made across most sectors this decade.

  - Net Zero refers to a state in which GHG emissions entering the atmosphere are balanced by removals out of the atmosphere. Reaching Net Zero CO_2 emissions globally is necessary for limiting global warming to any level. In most modelled scenarios, Net Zero global GHG emissions is associated with net negative global CO_2 emissions (needed to balance residual non-CO_2 emissions) and falling temperatures.[25]

  - Limiting warming requires both limiting cumulative CO_2 emissions and strong reductions in other GHGs. The IPCC has high confidence that the level of emissions reduction by 2030 will be key to determining whether warming can be limited to 1.5°C or 2°C.

  - Global warming will continue to increase in the near term, as cumulative CO_2 emissions continue to rise in all the IPCC's modelled scenarios. Even under the IPCC's very low emissions scenario, global warming is more likely than not to reach 1.5°C before 2040.

- Rapid action on mitigation and adaptation can reduce projected losses and damage. Actions this decade are crucial to reducing emissions quickly and adapting to the changing climate, since there are often long implementation times. Delaying action could also have other detrimental consequences, including risking lock-in to high-emissions infrastructure, stranded assets, and rising costs for people and businesses.

  - The IPCC reports a 10–23% climate change-caused decline in annual global GDP by 2100 under a high warming scenario, though statistical approaches point towards the upper end of this range.[26;27] Recent actuarial assessments emphasise the risk that losses could be considerably higher than currently considered in decision-making.[28;29]

  - Integrated responses that address both mitigation and adaptation objectives can take advantage of synergies and reduce trade-offs.

1.2 The UK and international context

Wales reports on its progress towards the formal global agreements on climate change as part of the UK. However, Wales' ambition in climate change is also set in a broader context of other state, private sector, and non-state action against climate change.*

* Further information on the international context and the global agreements to address climate change can be found in Chapter 1 of our Seventh Carbon Budget advice report.

1.2.1 Global agreements on climate change

The UNFCCC process

The UNFCCC is the UN process for negotiating a global approach to address climate change. 197 countries plus the European Union are currently party to this process. Negotiations take place through the annual Conference of the Parties (COP). COP21 in 2015 negotiated the Paris Agreement, which is the latest global agreement on climate change mitigation.

- **The Paris Agreement:** this set several goals and objectives extending across mitigation, adaptation, and finance, including:
  - A long-term temperature goal of limiting global warming to 'well below 2ºC above pre-industrial levels' and to 'pursue efforts to' limit warming to 1.5ºC above pre-industrial levels.
  - On mitigation, setting three high-level milestones for global GHG emissions: global peaking as soon as possible, rapid reductions thereafter, and achieving a balance between emissions sources and sinks in the second half of this century (Net Zero GHGs).
  - The UK has substantially reduced its emissions and has set targets consistent with reaching Net Zero emissions by 2050. Other developed economies such as the European Union are also committing to comparable targets (see Section 10.1.1 of the UK Seventh Carbon Budget advice report for more detail).
- **Nationally Determined Contributions:** under the Paris Agreement, countries are required to submit Nationally Determined Contributions (NDCs). NDCs should set out ambitious targets and plans to reduce emissions in line with the aims of the Agreement.
  - The UK set its first NDC to require a reduction in GHG emissions (excluding emissions from international aviation and shipping) of at least 68% by 2030, compared to 1990 levels.
  - In January 2025, the UK submitted its second NDC, requiring at least an 81% reduction in GHG emissions by 2035, compared to 1990 levels. Both NDCs have been set in line with the Committee's advice.
  - Wales reports on its international commitments formally to the UN as part of the UK-wide NDC.
- **The Global Stocktake:** the Paris Agreement established a five-yearly Global Stocktake to assess progress towards achieving its objectives. The first Global Stocktake concluded at COP28 in 2023 and highlighted significant gaps between current action and that needed to achieve the Agreement's goals, notably (in the context of this advice) on mitigation.
  - Reacting to the latest scientific evidence and political momentum built at COP26 and since, the Global Stocktake placed particular emphasis on the importance of 1.5ºC, underscoring that climate impacts would be much less severe than at 2ºC, and noting the gap between existing commitments and a 1.5ºC-consistent trajectory.
  - The Global Stocktake set out several global objectives, including:
    - A tripling of global renewable energy capacity and a doubling of the global average annual rate of energy efficiency improvements by 2030.
    - Accelerating the phase-down of unabated coal power and transitioning away from fossil fuels, with particular focus on accelerated action this decade.

- Accelerating reductions in non-CO_2 GHG emissions, including in particular methane by 2030.

- Accelerating deployment of low- and zero-emission technologies including zero-emission vehicles, renewables, nuclear, removals, and carbon capture technologies.

- Phasing out inefficient fossil fuel subsidies.

Global ambition and delivery

National Net Zero targets and ambitions now cover approximately 90% of present global GHG emissions. Many of these targets are assessed as lacking detail and credibility, with short-term ambitions out of step with long-term goals.[30]

These targets are increasingly accompanied by policy packages designed to incentivise take-up of low-carbon technologies and boost domestic energy security and low-carbon competitiveness, albeit still falling short of alignment with NDC targets. Major low-carbon transition programmes (often with a notable electrification focus) are underway in the world's largest economies.

Progress is being driven by improving economics of low-carbon technologies interacting with policy support. The global average cost for new electricity generation has fallen by 88% for solar PV, 60% for wind, and nearly 76% for battery storage since 2010.[31] The world now invests almost twice as much in clean energy as it does in fossil fuels, with clean energy investment expected to reach $2 trillion in 2024.[32]

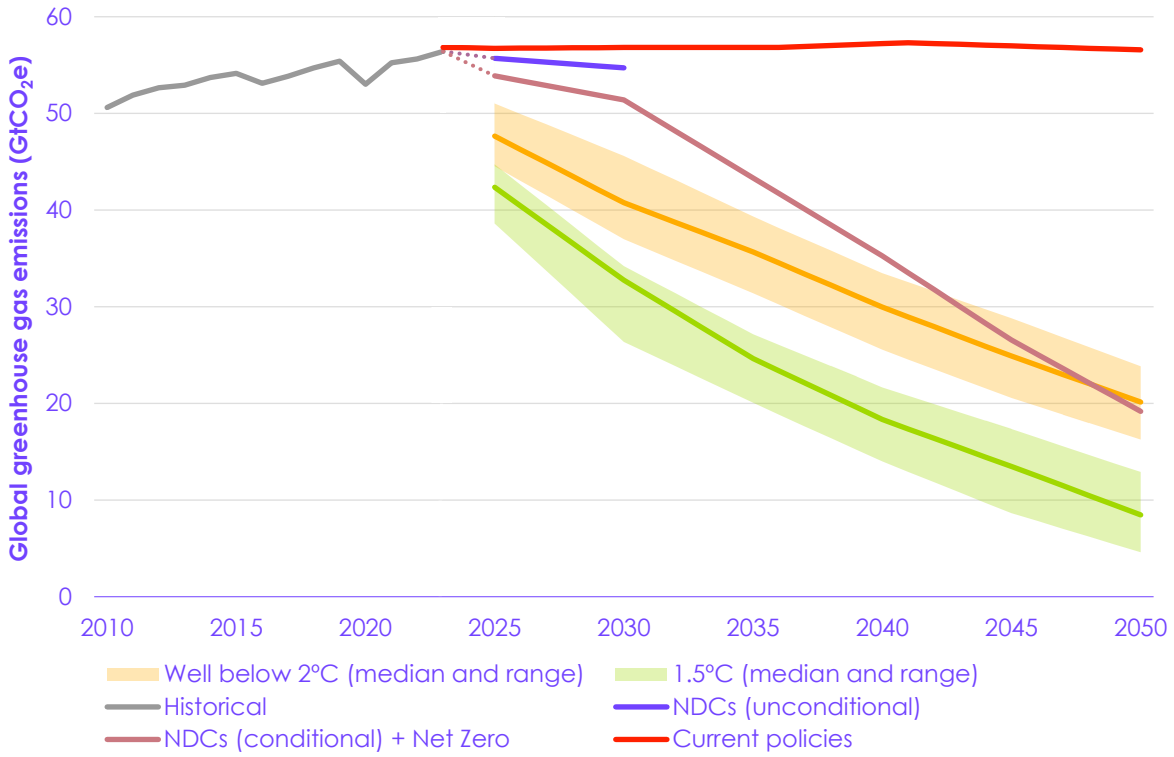
Globally, however, efforts remain significantly off track to achieve the Paris Agreement temperature goal (Figure 1.2).[*]

- Global GHG emissions implied by NDCs are consistent with warming of around 2.5°C by 2100 and would need to be 19–22 $GtCO_2e$ lower in 2030 than those implied by current NDCs to align with a 1.5°C scenario. Current policies in turn fall short of what would be needed to deliver NDCs, implying warming of around 3°C by 2100 and indicating an implementation gap on top of the ambition gap.[33;34]

- Nonetheless, significant progress has been made in recent years. When major emitters' Net Zero pledges are considered alongside NDCs, latest commitments imply warming below 2°C if implemented in full (which countries are not currently on track to do), compared to the 3–4°C projected before the Paris Agreement was adopted.[35]

[*] Several organisations project future warming using different methodologies and making different assumptions, particularly on long-term emissions trends. For simplicity, here we refer to warming estimates associated with a 50% probability from the UNEP Emissions Gap Report 2024, rounded to the nearest 0.5°C to avoid false precision.

Figure 1.2 Global GHG emissions under current ambition, compared to Paris-aligned trajectories



Description: Current policies and commitments imply flat or falling future global emissions, above scenarios consistent with limiting warming to 1.5°C or well below 2°C.
Source: Rogelj, J., Den Elzen, M.G.J. and Portugal Pereira, J. (2024) *The UNEP Emissions Gap Report 2024: No More Hot Air … Please! With a Massive Gap between Rhetoric and Reality, Countries Draft New Climate Commitments*.
Notes: (1) For simplicity, current policies and current ambition scenarios show median pathways only, masking a wider uncertainty range. Ranges shown for 1.5°C and well below 2°C scenarios are 20th–80th percentiles, as presented in the Emissions Gap Report but distinct from the ranges shown in Figure 10.2. (2) 1.5°C and well below 2°C scenarios generally assume cost-effective global action beginning in 2020. (3) Other than for current policies, scenario data is available from 2025 onwards – dotted lines joining historical to scenarios are for visual consistency only. (4) For consistency with the Emissions Gap Report source, but in contrast to UK emissions presented in this report, emissions here are presented in terms of global warming potentials from the Intergovernmental Panel on Climate Change's fourth assessment report. NDCs refer to Nationally Determined Contributions – emissions targets submitted by parties to the Paris Agreement.

1.2.2 The Climate Change Act and UK carbon budgets

The Climate Change Act (2008) is the UK's legal framework for tackling and responding to climate change. The Climate Change Act sets in law a long-term goal of reaching Net Zero UK GHG emissions by 2050 as well as intermediate steps defined by the level of carbon budgets, which set legally binding caps on UK GHG emissions over five-year periods. These make clear the required level of emissions reduction in the short and medium term to ensure the UK is on track to decarbonise by 2050.

- Emissions in Wales are covered by the Climate Change Act, and therefore contribute to the UK's carbon budgets and Net Zero target.
- The UK has approximately halved its emissions since 1990 and has met all of its three carbon budgets so far.
- The next three steps on the way to Net Zero are the Fourth, Fifth and Sixth Carbon Budgets, covering the periods 2023 to 2027, 2028 to 2032, and 2033 to 2037. These have been legislated, while the Seventh Carbon Budget, covering the period 2038 to 2042, is due to be legislated in 2026.

1.3 The Environment (Wales) Act

The Environment (Wales) Act 2016 sets the framework for the Welsh Government to address climate change. Emissions in Wales are covered by both Wales' targets, set under the Act, and UK-wide targets, set under the UK Climate Change Act (2008) and as part of the UNFCCC process (see Section 1.2.2).

- The Act has an ambitious target to reach Net Zero greenhouse gas emissions by 2050.
- The Act also sets out decadal targets and five-yearly carbon budgets, that started in 2016 (Table 1.1). The carbon budgets are expressed as average annual percentage reductions in emissions below the 1990 baseline.* Emissions from international aviation and shipping are included in these targets.
- The Act originally included a target to reduce emissions by at least 80% by 2050. The Committee's 2017 advice on the First (2016 to 2020) and Second (2021 to 2025) Carbon Budget targets, which was accepted by the Welsh Government, was based on this 80% target. In line with the Committee's advice in 2019 and 2020, the Welsh Government subsequently increased the ambition of its 2050 target to be Net Zero emissions.[36;37]
- This means that emissions will need to be reduced at a faster rate than envisaged when the First and Second Carbon Budget targets were set.† Wales' Third Carbon Budget (2026 to 2030), 2030, and 2040 targets were set, following the Committee's 2020 advice, at a level compatible with the Net Zero target.

Under the Act, the Committee is required to provide advice on the Fourth Carbon Budget, covering the period from 2031 to 2035. This report provides that advice. The Welsh Government needs to consider this advice and set the budget by the end of 2025.

Another significant piece of legislation that is relevant for addressing climate change is Wales is the Well-being of Future Generations (Wales) Act 2015.

- The Well-being of Future Generations Act places a duty on public bodies in Wales to improve the social, economic, environmental, and cultural well-being of Wales. To do this, they must set, publish, and take action to meet well-being objectives that show how they will work to achieve the vision for Wales set out in the well-being goals of the Well-being of Future Generations Act.
- We summarise how our pathway relates to each of the well-being goals of the Well-being of Future Generations Act in Section 4.3.

Through the Co-operation Agreement 2021, the Welsh Government established the Wales Net Zero 2035 Challenge Group to provide independent advice to examine potential pathways to Net Zero by 2035.[38] The Challenge Group developed a number of policy pathways of action, setting out approaches that could help achieve Net Zero earlier than 2050.[39]

* The baseline year is 1990 for CO_2, methane, and nitrous oxide and 1995 for F-gases. We refer to this as 'the 1990 baseline' throughout this advice.

† The Second Carbon Budget was adjusted to account for the earlier than expected closure of the Aberthaw coal power station, but even with this adjustment the target is insufficient to be on track for Net Zero.

Table 1.1
Wales' existing targets

Target period	Existing target (reduction on 1990 levels)
First Carbon Budget (2016–2020)	23% (achieved)
Second Carbon Budget (2021–2025)	37%
Third Carbon Budget (2026–2030)	58%
2030	63%
2040	89%
2050	100%

Source: Welsh Government (2018) *The Climate Change (Carbon Budgets) (Wales) Regulations 2018*; Welsh Government (2021) *The Climate Change (Interim Emissions Targets) (Wales) (Amendment) Regulations 2021*.
Notes: The percentage reductions for the carbon budgets are average annual reductions over the five-year periods. These are reductions compared to the baseline specified in the Act, which is 1990 for CO_2, methane, and nitrous oxide and 1995 for F-gases.

1.4 Current emissions in Wales

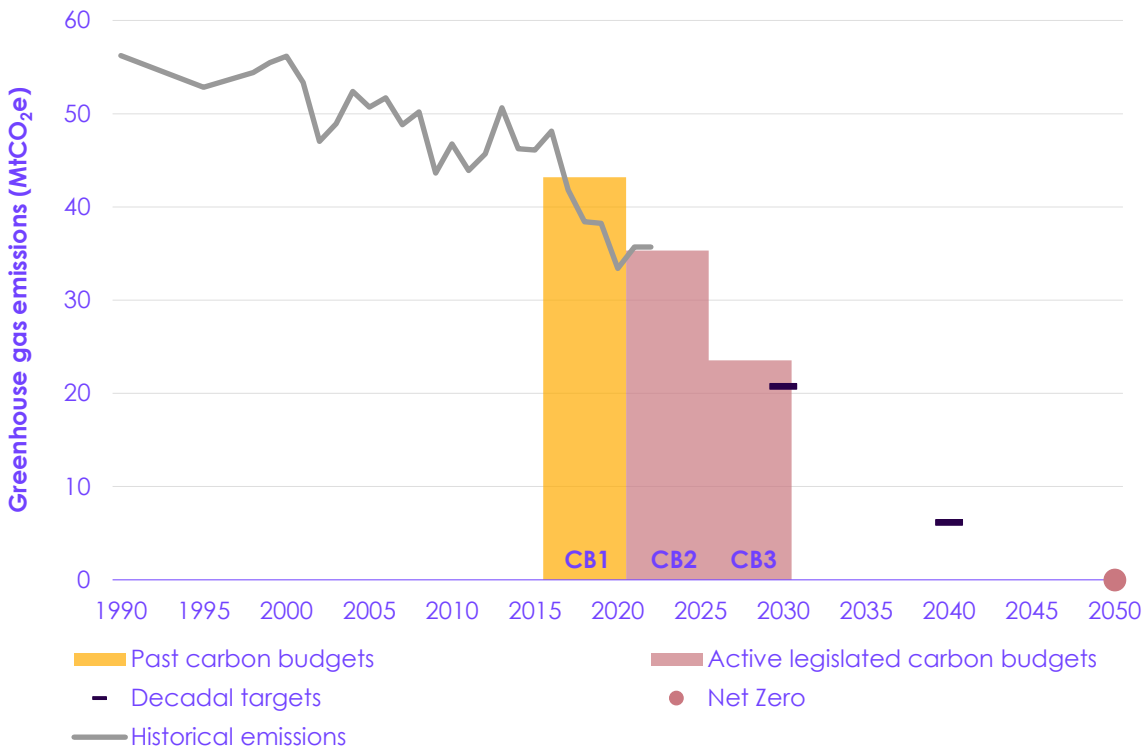
Emissions in Wales were 35.7 $MtCO_2e$ in 2022, the most recent year for which data is available (Figure 1.3).

- Emissions in 2022 were dominated by industry. However, more than half of industrial emissions were from the blast furnaces at the Port Talbot steelworks, which closed in 2024 and are due to be replaced with an electric arc furnace by 2027 (the handling of this transition is discussed in Box 4.1 in Chapter 4). Emissions are now likely to be dominated by electricity supply, agriculture, and surface transport, with significant contributions from other sectors (Figure 1.4).

- Emissions have fallen 37% since 1990. Since the Act was legislated, the pace of emissions reduction has accelerated, with over half this reduction having occurred since 2016.

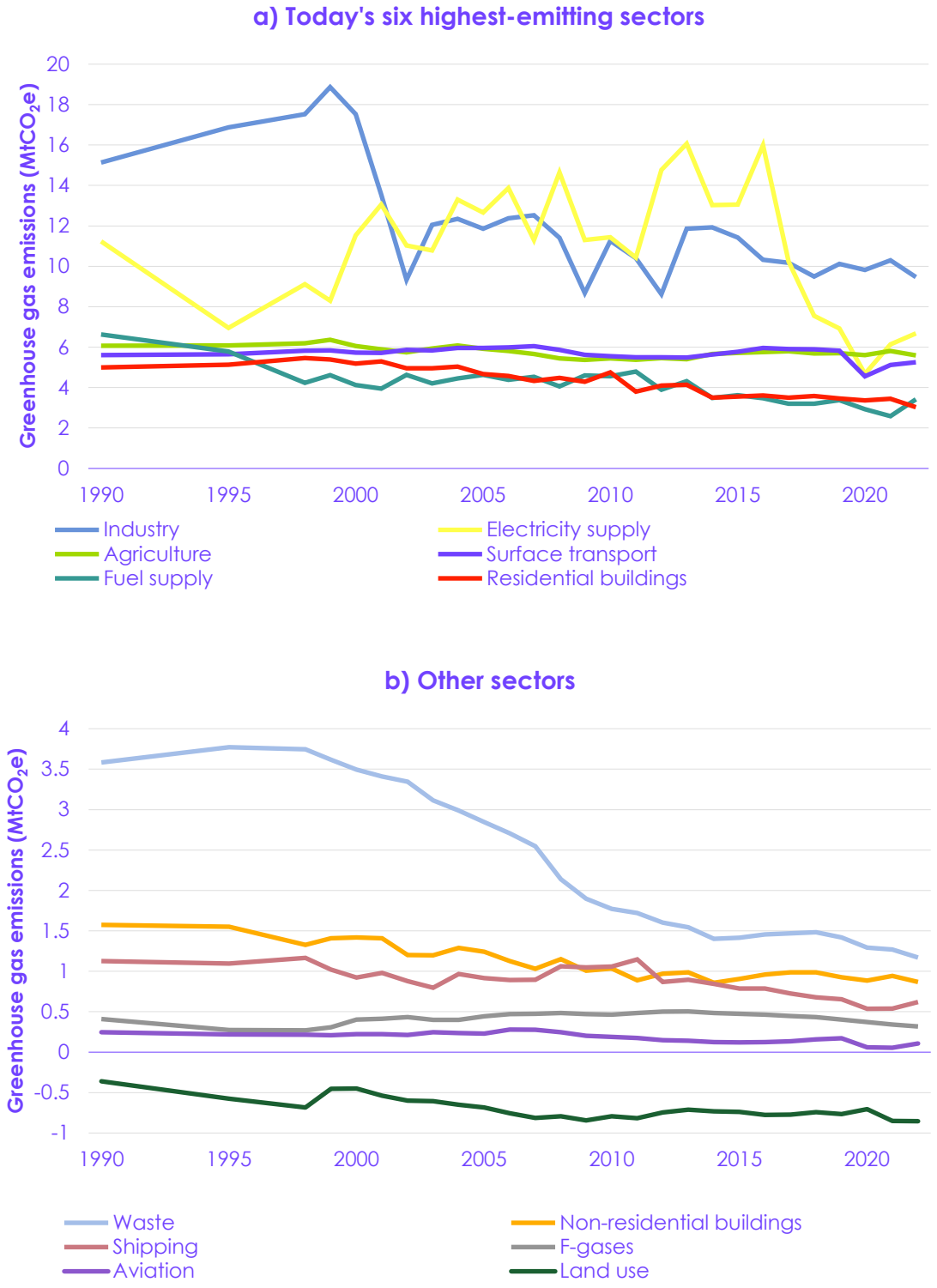
- So far, emissions reductions have been driven by the industry and electricity supply sectors due to reduced industrial output, the phase-out of coal, and the ramp-up of renewable electricity generation. There have also been significant reductions in the waste sector.

Figure 1.3 Wales' historical emissions and current targets



Description: Emissions in Wales were 35.7 $MtCO_2e$ in 2022, the most recent year for which data is available. This is 37% below levels in 1990.
Source: National Atmospheric Emissions Inventory (2024) *Greenhouse Gas Inventories for England, Scotland, Wales & Northern Ireland: 1990-2022*; CCC analysis.
Notes: 'CB' refers to Wales' carbon budgets: 'CB1' refers to the First Carbon Budget; subsequent numbers refer to subsequent carbon budgets.

Figure 1.4 Wales' historical emissions by sector



Description: The largest share of emissions in 2022 came from the industry sector, with significant contributions also coming from electricity supply, agriculture, and surface transport.
Source: National Atmospheric Emissions Inventory (2024) *Greenhouse Gas Inventories for England, Scotland, Wales & Northern Ireland: 1990-2022*; CCC analysis.

Endnotes

[1] Copernicus Climate Change Service (2025) *The 2024 annual climate summary: global climate highlights 2024*. https://climate.copernicus.eu/global-climate-highlights-2024.

[2] Copernicus Climate Change Service (2024) *Warmest January on record, 12-month average over 1.5°C above preindustrial*. https://climate.copernicus.eu/warmest-january-record-12-month-average-over-15degc-above-preindustrial.

[3] World Meteorological Organization (2024) *State of the Global Climate 2023*. https://library.wmo.int/idurl/4/68835.

[4] Palazzo Corner, S. et al (2023) *The Zero Emissions Commitment and climate stabilization*. Frontiers in Science. https://doi.org/10.3389/fsci.2023.1170744.

[5] Rogelj, J., Schleussner, C.-F., and Hare, W. (2017) *Getting it right matters: Temperature goal interpretations in geoscience research*. Geophysical Research Letters. https://doi.org/10.1002/2017GL075612.

[6] Forster, P. et al (2024) *Indicators of Global Climate Change 2023: annual update of key indicators of the state of the climate system and human influence*. Earth Syst. Sci. https://doi.org/10.5194/essd-16-2625-2024.

[7] Copernicus Climate Change Service (2024) *Copernicus: June 2024 marks 12th month of global temperature reaching 1.5°C above pre-industrial*. https://climate.copernicus.eu/copernicus-june-2024-marks-12th-month-global-temperature-reaching-15degc-above-pre-industrial.

[8] Copernicus Climate Change Service (2025) *The 2024 annual climate summary: global climate highlights 2024*. https://climate.copernicus.eu/global-climate-highlights-2024.

[9] United Nations Environment Programme (2023) *Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again)*. https://doi.org/10.59117/20.500.11822/43922.

[10] United Nations Environment Programme (2024) *Emissions Gap Report 2024: No more hot air … please! With a massive gap between rhetoric and reality, countries draft new climate commitments*. https://doi.org/10.59117/20.500.11822/46404.

[11] International Energy Agency (2024) *World Energy Outlook 2024*. https://www.iea.org/reports/world-energy-outlook-2024.

[12] Met Office (2023) *What do we mean by a climate tipping point?* https://www.metoffice.gov.uk/blog/2023/what-do-we-mean-by-a-climate-tipping-point.

[13] Schleussner, C.-F. et al (2024) *Overconfidence in climate overshoot*. Nature. https://doi.org/10.1038/s41586-024-08020-9.

[14] Intergovernmental Panel on Climate Change (2021*) Summary for Policymakers. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. https://www.ipcc.ch/report/ar6/wg1/.

[15] Smith, C. et al (2024) *ClimateIndicator/data: Indicators of Global Climate Change 2023 revision (v2024.05.29b)*. Zenodo. https://doi.org/10.5281/zenodo.11388387.

[16] Intergovernmental Panel on Climate Change (2021) *Summary for Policymakers. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. https://www.ipcc.ch/report/ar6/wg1/.

[17] Crippa et al. (2024) *GHG emissions of all world countries*. Publications Office of the European Union, Luxembourg. https://doi.org/10.2760/4002897.

[18] Gütschow, J., Busch, D., Pflüger, M. (2024) *The PRIMAP-hist national historical emissions time series v2.6 (1750-2023)*. Zenodo. https://doi:10.5281/zenodo.13752654.

[19] Smith, C. et al (2024) *ClimateIndicator/data: Indicators of Global Climate Change 2023 revision (v2024.05.29b)*. Zenodo. https://doi.org/10.5281/zenodo.11388387.

[20] Gütschow, J., Busch, D., Pflüger, M. (2024) *The PRIMAP-hist national historical emissions time series v2.6 (1750-2023)*. Zenodo. https://doi:10.5281/zenodo.13752654.

[21] World Bank (2023) *Population, Total*. https://data.worldbank.org/indicator/SP.POP.TOTL. (Accessed: 10 December 2024).

[22] International Energy Agency (2024) *World Energy Outlook 2024*. https://www.iea.org/reports/world-energy-outlook-2024.

[23] Bloomberg New Energy Finance (2024) *New Energy Outlook 2024*. https://about.bnef.com/new-energy-outlook/. (Accessed: 10 December 2024).

[24] United Nations Framework Convention on Climate Change (2024) *Nationally determined contributions under the Paris Agreement. Synthesis report by the secretariat*. https://unfccc.int/documents/641792.

[25] Riahi, K. et al (2022) *Mitigation pathways compatible with long-term goals. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi:10.1017/9781009157926.005. https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter03.pdf.

[26] O'Neill, B. et al (2022) *Key Risks Across Sectors and Regions. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2411–2538, doi:10.1017/9781009325844.025. https://www.ipcc.ch/report/ar6/wg2/.

[27] Burke, M., Hsiang, S., and Miguel, E. (2015) *Global non-linear effect of temperature on economic production*. Nature 527, 235–239. https://doi.org/10.1038/nature15725.

[28] Trust, S. et al (2023) *The emperor's new climate scenarios*. https://actuaries.org.uk/emperors-new-climate-scenarios.

[29] Trust, S. et al (2024) *Climate scorpion: the sting is in the tail*. https://actuaries.org.uk/media/g1qevrfa/climate-scorpion.pdf.

[30] United Nations Environment Programme (2023) *Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again)*. https://doi.org/10.59117/20.500.11822/43922.

[31] International Energy Agency (2024) *Breakthrough Agenda Report 2024*. https://www.iea.org/reports/breakthrough-agenda-report-2024.

[32] International Energy Agency (2024) *World Energy Investment 2024*. https://www.iea.org/reports/world-energy-investment-2024.

[33] United Nations Environment Programme (2024) *Emissions Gap Report 2024: No more hot air … please! With a massive gap between rhetoric and reality, countries draft new climate commitments*. https://doi.org/10.59117/20.500.

[34] International Energy Agency (2024) *World Energy Outlook 2024*. https://www.iea.org/reports/world-energy-outlook-2024.

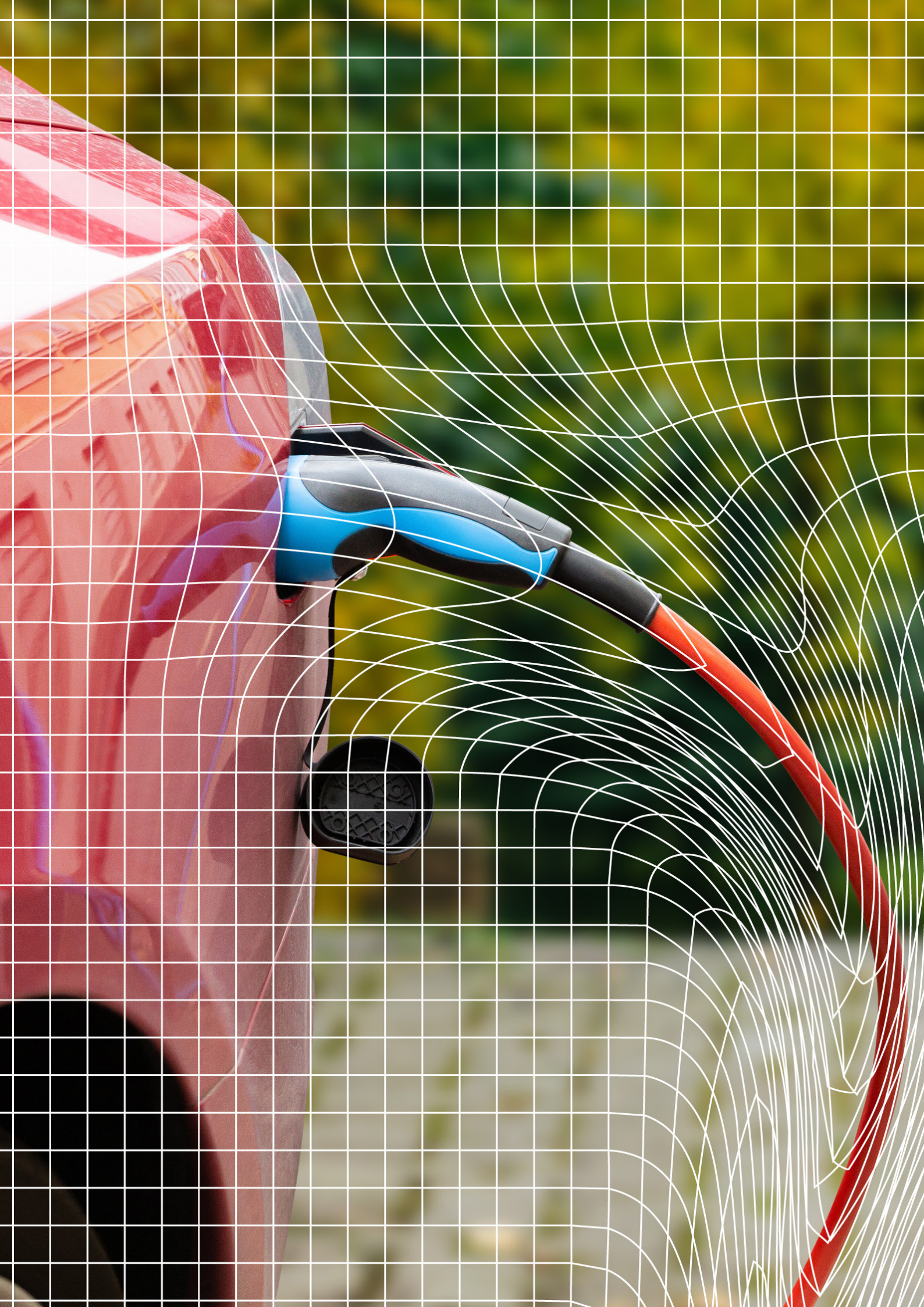
[35] United Nations Environment Programme (2015) *The Emissions Gap Report 2015*. https://www.unep.org/resources/emissions-gap-report-2015.

[36] Climate Change Committee (2019) *Net Zero – The UK's contribution to stopping global warming*. https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/.

[37] Climate Change Committee (2020) *The path to Net Zero and progress on reducing emissions in Wales*. https://www.theccc.org.uk/publication/the-path-to-net-zero-and-progress-reducing-emissions-in-wales/.

[38] Welsh Government (2021) *The Co-operation Agreement*. https://www.gov.wales/sites/default/files/publications/2021-11/cooperation-agreement-2021.pdf.

[39] Wales Net Zero 2035 Challenge Group (2024) *Summary report: Pathways to a prosperous and resilient Wales in a changing future*. https://netzero2035.wales/our-reports/1-summary-report/.



Chapter 2: Wales' path to Net Zero

Introduction and key messages

This chapter sets out our recommended level for Wales' Fourth Carbon Budget. Our recommendation is based on our Balanced Pathway for Wales from 2025 to Net Zero by 2050.

Our key messages are:

- The Fourth Carbon Budget should be set at an average annual reduction of 73% on 1990 levels for the period from 2031 to 2035, including Wales' share of international aviation and shipping emissions.
- The Welsh Government should plan to deliver the emissions reductions required to meet the Fourth Carbon Budget through domestic decarbonisation action within Wales. The Welsh Government should not plan to use international credits (referred to as 'carbon units' in the Act) to achieve the Fourth Carbon Budget.
- This will require the recent pace of emissions reduction to be maintained. Achieving this will depend largely on ramping up deployment of solutions that are available today. Electrification of key technologies is the key driver of the emissions reduction required to achieve the Fourth Carbon Budget.
  - Electrification, including the supply of low-carbon electricity and its use in electric vehicles (EVs), heat pumps, and industrial processes, delivers two-thirds of the emissions reduction needed.
  - Many of the solutions required are available today with choices that are now clear. These solutions could be rapidly deployed, provided the right incentives are put in place. This is crucial, as the end of the Fourth Carbon Budget period is only a decade away – using established, available solutions is vital to meeting it.
  - The other key routes (low-carbon fuels and carbon capture and storage, nature, and engineered removals) will be less important for the Fourth Carbon Budget but needed for the 2040 and 2050 targets.
  - Rates of tree planting and peatland restoration (including on land released from agriculture) need to ramp up from today, to deliver substantial carbon sequestration in nature by the later years of the pathway. This allows the combined agriculture and land use sectors to reach Net Zero emissions in Wales by 2050.
- Given the balance of investment costs and operating savings, the overall cost of meeting the Balanced Pathway for Wales is estimated to be around £390 million per year on average between 2025 and 2050, relative to a baseline pathway of no further decarbonisation action. This is around 0.4% of GDP.

2.1 The Balanced Pathway for Wales

2.1.1 The Balanced Pathway

Our advice on Wales' Fourth Carbon Budget is based on our Balanced Pathway, which represents our assessment of an ambitious but deliverable pathway for Wales to reach Net Zero by 2050.

- Our pathway includes all greenhouse gases (GHGs) and covers the period 2025 to 2050. It includes Wales' share of international aviation and shipping emissions.

- The pathway is aligned with Wales' contribution to the UK's Balanced Pathway, which we presented in our advice on the UK's Seventh Carbon Budget. The UK's Balanced Pathway represents our assessment of a pathway to Net Zero UK GHG emissions that is based on actions that are feasible and cost effective across the UK and takes into account the different resources, opportunities, and costs seen in different parts of the UK. Therefore, the Balanced Pathway for Wales also represents a credible contribution for Wales to the UK's pathway to Net Zero.

2.1.2 Emissions in the Balanced Pathway

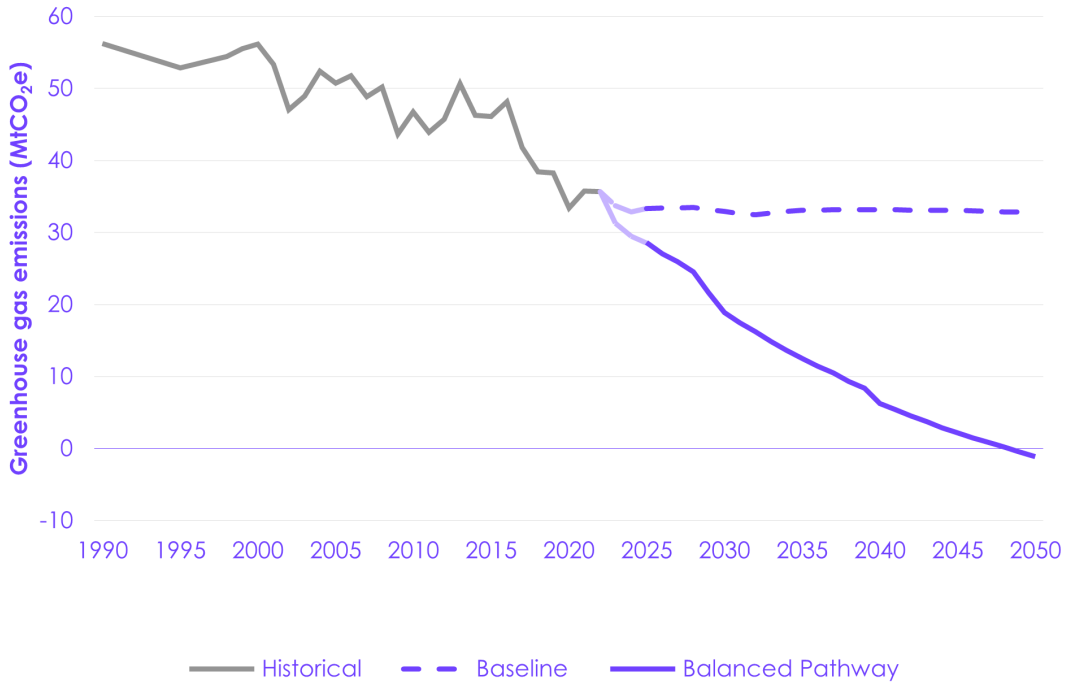
Delivering the Balanced Pathway would maintain the momentum built since the introduction of the Environment (Wales) Act in 2016. It requires the recent pace of emissions reductions to be maintained over the coming decades (Figure 2.1).

- Since 2016, emissions in Wales have fallen by around 2 $MtCO_2e$ per year, on average. A similar pace of reduction is needed between now and the early 2030s in the Balanced Pathway.

- Much of this reduction will come from technologies and choices that are available today and can be deployed quickly (see Section 2.3.2). This emphasises the importance of putting the conditions in place to enable low-carbon markets and choices to scale up quickly.

- The Balanced Pathway is presented compared to a baseline pathway of no further decarbonisation action. This allows us to calculate the required abatement, investment needs, costs, and cost savings associated with the future actions to reduce Wales' GHG emissions. See Chapter 2 of our UK Seventh Carbon Budget advice for further details on our baseline and the general approach we take to developing emissions pathways.

Figure 2.1 The Balanced Pathway to Net Zero and the Fourth Carbon Budget in Wales



Description: Emissions fall quickly in the Balanced Pathway, continuing the momentum built since the introduction of the Environment Act (Wales) in 2016.
Source: National Atmospheric Emissions Inventory (2024) *Greenhouse Gas Inventories for England, Scotland, Wales & Northern Ireland: 1990-2022*; CCC analysis.
Notes: (1) Our pathway and baseline are modelled using historical data up to 2022. Emissions reductions prior to 2025 are based largely on existing trends; additional decarbonisation measures only begin to be applied in our modelling after 2025. (2) The fall in baseline emissions in 2023 and 2024 is due to a fall in iron and steel production assumed in the Government's Energy and Emissions Projections, which we used as the basis for our UK-wide baseline.

2.2 Emissions in the Balanced Pathway

2.2.1 Performance against existing future emissions targets

The Balanced Pathway meets all of Wales' existing targets on GHG emissions (Table 2.1).

- The pathway outperforms the Second Carbon Budget, which was set in line with the previous 80% emissions reduction target for 2050. Outperforming this target is necessary to ensure a feasible path to Net Zero.
  - Similarly, Wales outperformed its First Carbon Budget, reducing emissions by 28% compared to the target of 23%. This target was also set in line with the previous 80% reduction goal.
- It narrowly meets both the Third Carbon Budget and 2040 interim target and overachieves the 2030 interim target due to an acceleration in emissions reductions in the late 2020s, largely in the electricity supply sector (see Box 3.1 for discussion of uncertainty in electricity supply emissions), after a slower rate in the mid-2020s. These remain ambitious targets, and rapid decarbonisation will be needed now to achieve them.

- The Balanced Pathway goes slightly beyond Net Zero in 2050. This is because our analysis assumes that a portion of the direct air carbon capture and storage (DACCS) required to meet Net Zero across the UK is located in Wales (see Section 2.4).

Table 2.1
Performance of the Balanced Pathway against Wales' existing GHG emissions targets

Target	Target level (reduction on 1990 levels)	Pathway performance
Second Carbon Budget (2021–2025)	37%	43%
Third Carbon Budget (2026–2030)	58%	58%
2030	63%	67%
2040	89%	89%
Net Zero 2050	100%	102%

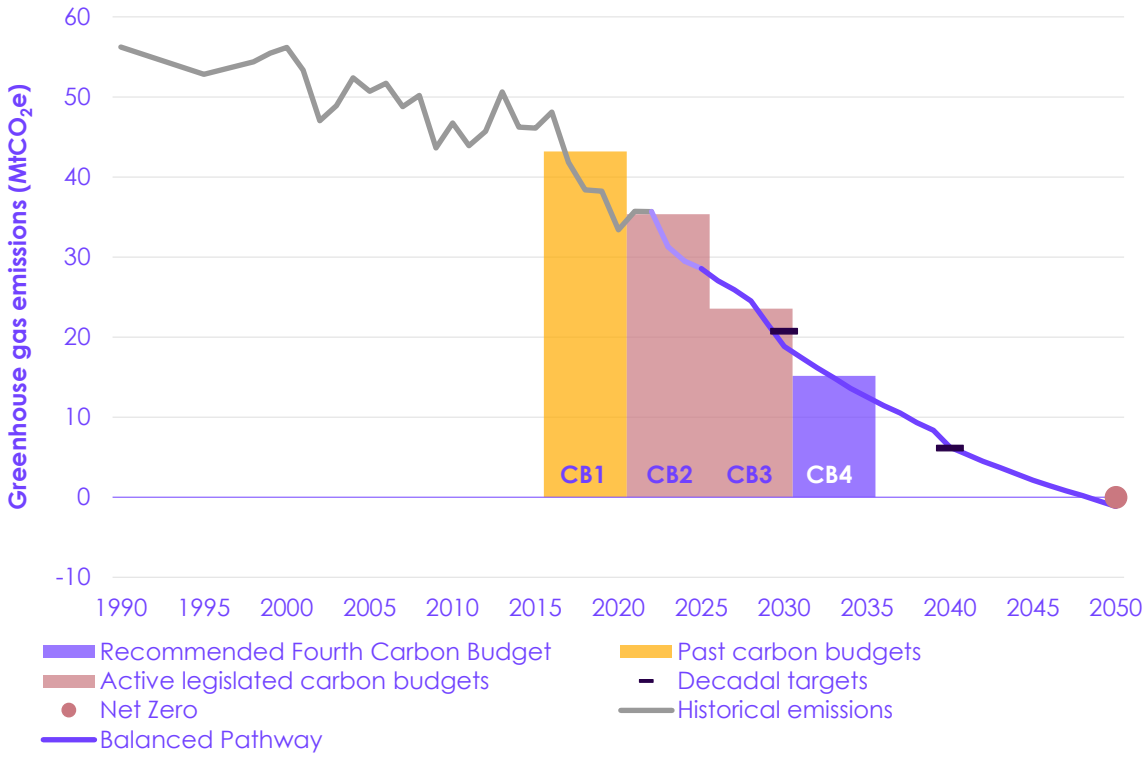
Notes: (1) All targets and pathway reductions include emissions from international aviation and shipping. (2) The percentage reductions for the carbon budgets are average annual reductions over the five-year periods. (3) Figures have been rounded to the nearest percentage point.

2.2.2 Recommended level of the Fourth Carbon Budget

The Committee recommends that the Fourth Carbon Budget should be set at an average annual reduction of 73% on 1990 levels for the period from 2031 to 2035 (Figure 2.2).

- The recommended 73% reduction would represent a continuation of the pace of progress required by Wales' existing emissions targets.
  - It would require emissions to fall by 15 percentage points between the Third and Fourth Carbon Budgets, which is the same reduction as required between the Second and Third Carbon Budgets.
  - It also represents a sensible stepping stone between the existing 2030 and 2040 interim targets.
  - It would correspond to emissions falling by 59% compared to today's levels by 2033.
- The Welsh Government should plan to deliver the emissions reductions required to meet the Fourth Carbon Budget through domestic decarbonisation action within Wales. The Welsh Government should not plan to use international credits (referred to as 'carbon units' in the Act) to achieve the Fourth Carbon Budget.

Figure 2.2 The recommended Fourth Carbon Budget



Description: The Committee recommends that the Fourth Carbon Budget should be set at an average annual reduction of 73% below the 1990 baseline for the period 2031–2035.
Source: National Atmospheric Emissions Inventory (2024) *Greenhouse Gas Inventories for England, Scotland, Wales & Northern Ireland: 1990-2022*; CCC analysis.
Notes: (1) Our pathway and baseline are modelled using historical data up to 2022. Emissions reductions prior to 2025 are based largely on existing trends; additional decarbonisation measures only begin to be applied in our modelling after 2025. (2) 'CB' refers to Welsh carbon budgets: 'CB1' refers to the First Carbon Budget; subsequent numbers refer to subsequent carbon budgets.

2.2.3 Contribution to meeting the UK's emissions targets

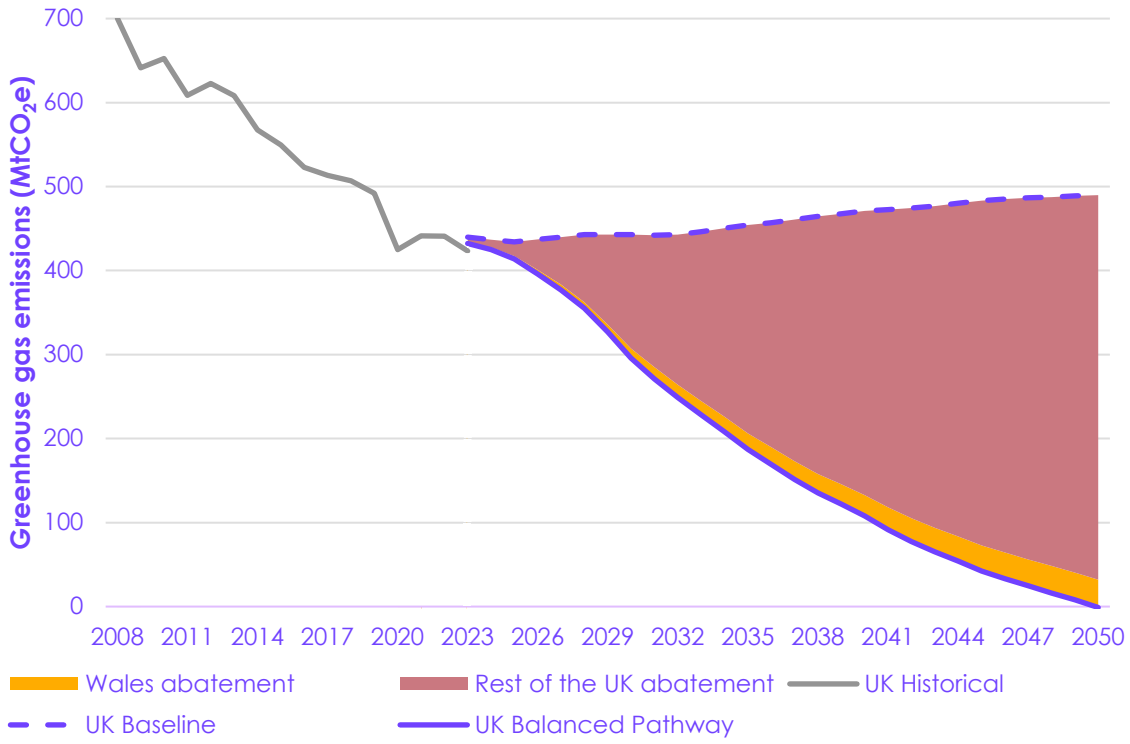
Emissions reductions in Wales deliver around 7% of the overall abatement required to meet the UK's recommended Seventh Carbon Budget and Net Zero target (Figure 2.3).

- The figure shows Wales' contribution to meeting the UK's Balanced Pathway to Net Zero. Around the Fourth Carbon Budget period, the UK's Balanced Pathway meets the UK's 2030 Nationally Determined Contribution (requiring a 68% reduction in emissions excluding international aviation and shipping by 2030, compared to 1990 levels) and the Sixth Carbon Budget (requiring a reduction in emissions of 78% by 2033–2037).

- Wales' contribution to projected UK-wide emissions reductions is similar to Wales' share of total current UK emissions (around 8%). On a proportionate basis, emissions fall slightly more in Wales than in the UK as a whole by the UK's Seventh Carbon Budget period (an 89% reduction on 1990 levels by 2040, compared with an 87% reduction in the UK Balanced Pathway). This is due to Wales' lower share of emissions from the aviation sector, which decarbonises at a similar pace to most other sectors, but starting later.*

* This includes aviation's share of engineered removals.

Figure 2.3 Wales' contribution to the UK-wide Balanced Pathway



Description: The emissions reductions in the Balanced Pathway for Wales deliver around 7% of the overall abatement required to meet the UK's recommended Seventh Carbon Budget and Net Zero target.
Source: Department for Energy Security and Net Zero (DESNZ) (2024) *Final UK greenhouse gas emissions national statistics: 1990 to 2022*; CCC analysis.
Notes: (1) The chart shows our UK-wide Seventh Carbon Budget Balanced Pathway and the share of emissions reduction that emissions reduction in Wales contributes to this. (2) The UK-wide pathway and baseline are modelled using historical data up to 2022 or 2023, depending on the sector. Emissions reductions prior to 2025 are based largely on existing trends; additional decarbonisation measures only begin to be applied in our modelling after 2025. (3) Emissions from international aviation and shipping are included. (4) The gap between historical 2023 emissions and our modelling for that year is largely because our analysis assumes that some of the emissions reduction from buildings between 2021 and 2023 was a short-term response to weather and high gas prices and because our shipping modelling is based on an activity-based estimate of emissions.

2.3 Drivers of emissions reduction in the Balanced Pathway

2.3.1 Emissions by greenhouse gas

The Balanced Pathway reaches Net Zero across all GHGs in 2049. Net Zero CO_2 emissions are achieved sooner, in 2043 (Figure 2.4). This represents a credible contribution for Wales to the UK's pathway to Net Zero.

- Delivering the pathway requires a continuation in the recent pace of CO_2 emissions reduction.
  - Wales reaches Net Zero CO_2 two years earlier than the UK-wide Balanced Pathway. This is because of the smaller share of Welsh emissions coming from aviation, which is dominated by CO_2 emissions and decarbonises later than other sectors.

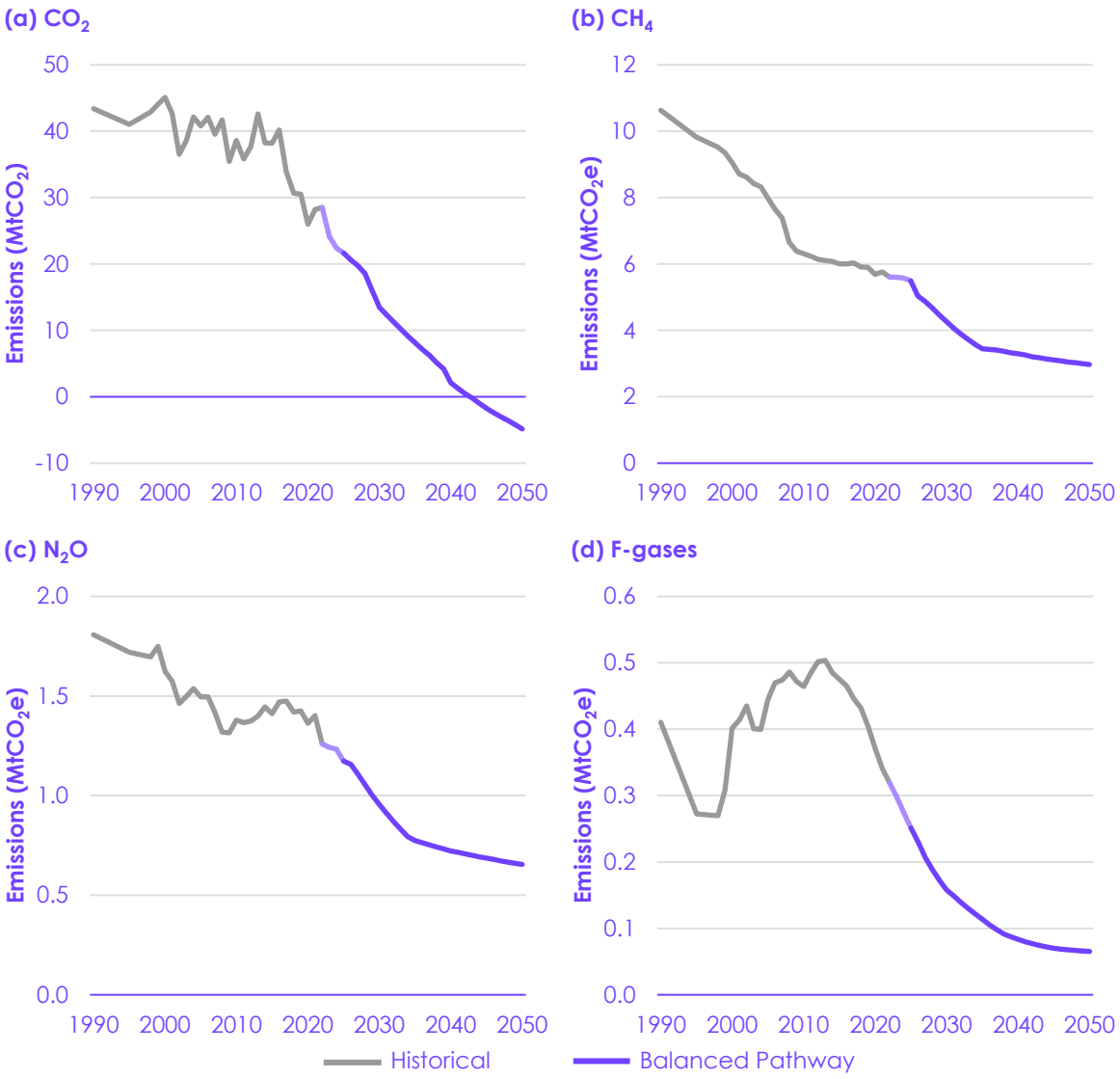
  - CO_2 reductions in our pathway come mostly from the roll-out of low-carbon technologies displacing fossil fuel combustion, along with reduced demand for high-carbon activities and deployment of engineered and land-based CO_2 removals.

- Methane (CH_4) emissions fall in the 2020s and early 2030s. This is mostly due to the impact of on-farm measures and diversification away from red meat and dairy production in agriculture, and reductions in methane generation at landfills. Wales saw large reductions in methane emissions during the 1990s and 2000s, primarily due to reductions in waste and fuel supply emissions, although these have since plateaued.

- Nitrous oxide (N_2O) emissions fall in the 2020s and early 2030s. Reductions come mainly in the agriculture sector, along with smaller reductions from reduced fossil fuel combustion across other sectors.

- Emissions of fluorinated gases (F-gases) continue recent trends of falling quickly. These are discussed in Section 3.2.10.

Figure 2.4 The Balanced Pathway by greenhouse gas



Description: Net Zero CO_2 emissions are achieved in 2043. There are also strong reductions in other greenhouse gas emissions.
Source: National Atmospheric Emissions Inventory (2024) *Greenhouse Gas Inventories for England, Scotland, Wales & Northern Ireland: 1990-2022*; CCC analysis.
Notes: Our pathway is modelled using historical data up to 2022. Emissions reductions prior to 2025 are based largely on existing trends; additional decarbonisation measures only begin to be applied in our modelling after 2025.

2.3.2 Sources of abatement

The end of the Fourth Carbon Budget period is only a decade away. Therefore, meeting this will depend mostly on solutions that are available today, the vast majority of which come from electrification of key technologies across the economy and measures to reduce demand for high-carbon activities (Figure 2.5). Later in the pathway, low-carbon fuels and carbon capture and storage (CCS), nature, and engineered removals play more of a role in reducing emissions in areas in which electrification is not feasible.

- **Electricity:** electrification delivers 67% of the total emissions reduction required by 2033 in the Balanced Pathway. Electric technologies are now the clear low-carbon technology choice in many areas (including surface transport and home heating). They are available today and could be deployed rapidly in many key areas, provided the right incentives are put in place. Scaling up these immediate options is key to meeting the Fourth Carbon Budget. Electrification of industry is driven by the transition of the Port Talbot steelworks to an electric arc furnace (the handling of this transition is discussed in Box 4.1 in Chapter 4).

- **Low-carbon farming, low-carbon fuels, and CCS:** other low-carbon technologies play a supporting role. This includes small initial deployment of hydrogen and CCS, whose roles grow later in the pathway to address sources of emissions that are less suited for electrification. In addition, a number of low-carbon farming practices and technologies are introduced in our pathway. Together these measures contribute a further 10% of the total emissions reduction required by 2033.

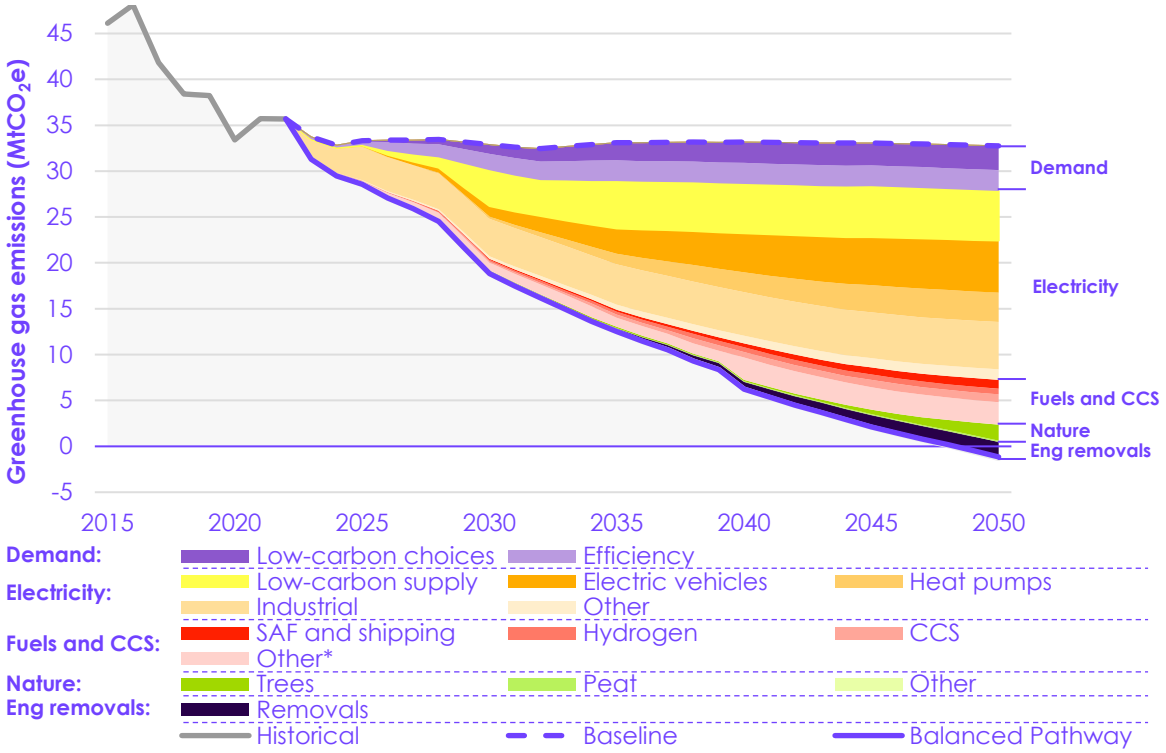
- **Demand:** measures to reduce demand for high-carbon activities can be enacted from today and are particularly important to reduce emissions while technologies are still transitioning. They contribute 21% of the total emissions reduction required by 2033. This includes measures to increase energy efficiency in homes, more efficient use of resources in industry, and reductions in commercial, household, and food waste. There are also some sustained shifts away from high-carbon activities, including a shift to public transport and active travel and a reduction in livestock numbers driven by reductions in meat consumption across the UK and measures to incentivise farmers to diversify income streams. Flying remains close to today's levels until technology develops.

- **Nature:** while land-based actions contribute only 1% of the emissions reduction required by 2033, these measures can also bring a wider range of benefits, including to nature in Wales. In addition, the role of carbon sequestration in new woodlands grows substantially in the later years of the pathway, playing an essential role in balancing emissions to meet Net Zero. Together with renewables, they provide opportunities for Welsh farmers and land managers to diversify their income streams away from livestock farming. Early action is vital to release land from agriculture to enable its use to grow these natural carbon sinks: increased tree planting rates in the 2020s are necessary to deliver the required levels of sequestration by 2050, while higher levels of peatland restoration reduce peatland emissions.

- **Engineered removals:** the only engineered removal that will be operating at scale by the Fourth Carbon Budget period is bioenergy with CCS (BECCS), predominantly at Wales' energy from waste (EfW) plants. BECCS contributes 2% of the total emissions reduction required by 2033. However, the introduction of DACCS along with other uses of BECCS and smaller contributions from enhanced weathering and biochar mean that the share of emissions reductions from engineered removals grows in the later years of our pathway.

The breakdown of emissions reduction required to meet the Fourth Carbon Budget is broadly similar to that required in our Balanced Pathway to meet the UK's Seventh Carbon Budget (Table 2.2). There is a greater share of emissions reductions from electrification in Wales by 2033 due to the electrification of the Port Talbot steelworks (the handling of this transition is discussed in Box 4.1 in Chapter 4).

Figure 2.5 Sources of abatement in the Balanced Pathway



Description: The Fourth Carbon Budget is delivered through five key routes: electricity, low-carbon fuels and CCS, nature, engineered removals, and demand. The largest share of emissions reduction is from the switch from fossil fuels to electric technologies powered using low-carbon electricity.
Source: CCC analysis.
Notes: (1) 'Electric vehicles' includes electrification of cars, vans, motorcycles, buses, and HGVs. 'Heat pumps' includes heat pumps for heating or hot water in residential, public, and commercial buildings (including those used in communal heating and heat networks). 'Industrial electrification' covers all electricity use in industry, including for heating, machinery, and other industrial processes. 'Low-carbon supply' shows the abatement from decarbonising electricity generation. All of these are enabled by improvements to the grid. (2) 'CCS' covers the abatement due to the direct use of CCS to capture CO_2 from emitting processes outside the electricity system – it is also used, alongside hydrogen, to enable long-term storable, dispatchable power in the electricity supply sector and to underpin engineered removals. (3) 'SAF' refers to sustainable aviation fuel. (4) 'Eng removals' refers to engineered removals. (5) *The increase in abatement in 2040 is due to reductions in fuel supply emissions at Pembroke refinery as demand for oil reduces, which we capture within the other category within low-carbon fuels and CCS. The other category within low-carbon fuels and CCS also includes low-carbon farming practices, such as the use of methane-suppressing feed additives.

Table 2.2
Comparison of abatement sources in Wales and the UK as a whole

	Share of emissions reduction by 2033 in Wales	Share of emissions reduction by 2033 in the UK
Electricity	67%	55%
Low-carbon fuels and CCS	10%	10%
Nature	1%	2%
Engineered removals	2%	4%
Demand	21%	29%

2.4 Emissions and removals in 2050

By 2050, the main source of residual emissions in Wales will be agriculture, with much smaller contributions from industry, waste, and other sectors. In our pathway, residual emissions are offset by negative emissions from land use sinks and engineered removals (Figure 2.6). As in our UK-wide advice, emissions in agriculture balance emissions in land use.

- Remaining emissions in agriculture and land use are balanced by the carbon sequestered by land-based sinks in the Balanced Pathway, leading to a slight net sink in the two sectors combined. In Wales, this is almost all sequestration in new woodlands, which requires ambitious action to scale up tree planting this decade (see Section 3.2.3). New woodlands also contribute to the aims of sustainable management of natural resources in Wales (see Section 4.4).

- Our modelling assumes that the residual emissions from other sectors are offset by engineered removals located in Wales. This includes BECCS, DACCS, and a small contribution from enhanced weathering and biochar (see Section 3.2.12).

  - The amount of DACCS required across the UK is determined in order to meet the UK's 2050 Net Zero target. In our analysis, this is then assumed to be shared equally between each of the four CCS clusters, including HyNet, which we model as equally split between Wales and England. This means that one-eighth of total UK DACCS is allocated to Wales (see Section 3.2.12). As a result, the available removals exceed total residual emissions and so emissions in Wales become net negative by 2050.

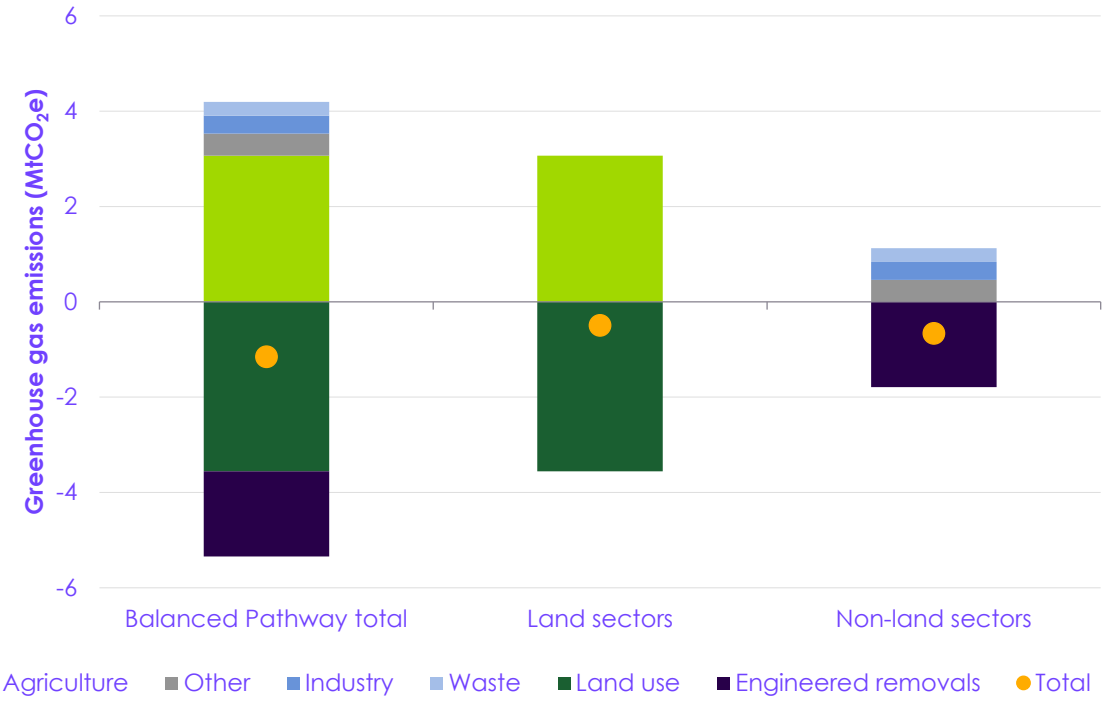
    - At a UK level, the largest source of residual emissions is from aviation. Therefore, these surplus removals in Wales are likely to be offsetting some aviation emissions associated with flights to or from the rest of the UK. As many Welsh residents take flights from English airports, this will play a role in reducing Wales' wider emissions footprint (see Section 3.2.11).

    - The exact proportion of UK removals that will be located in Wales is unknown and may be less than we have modelled. There is some room for a smaller proportion to be situated in Wales with Wales still achieving Net Zero emissions by 2050.

  - Who pays for engineered removals is a policy choice. Outside the agriculture sector, the Balanced Pathway largely assumes a 'polluter pays' principle, where those sectors with residual emissions are expected to reduce their net contribution to UK emissions, whether through in-sector emissions reductions or using removals to offset ongoing emissions. As a result, a large portion of the cost of the removals in Wales could be expected to be funded by industries (especially aviation) that have residual emissions UK-wide in 2050.

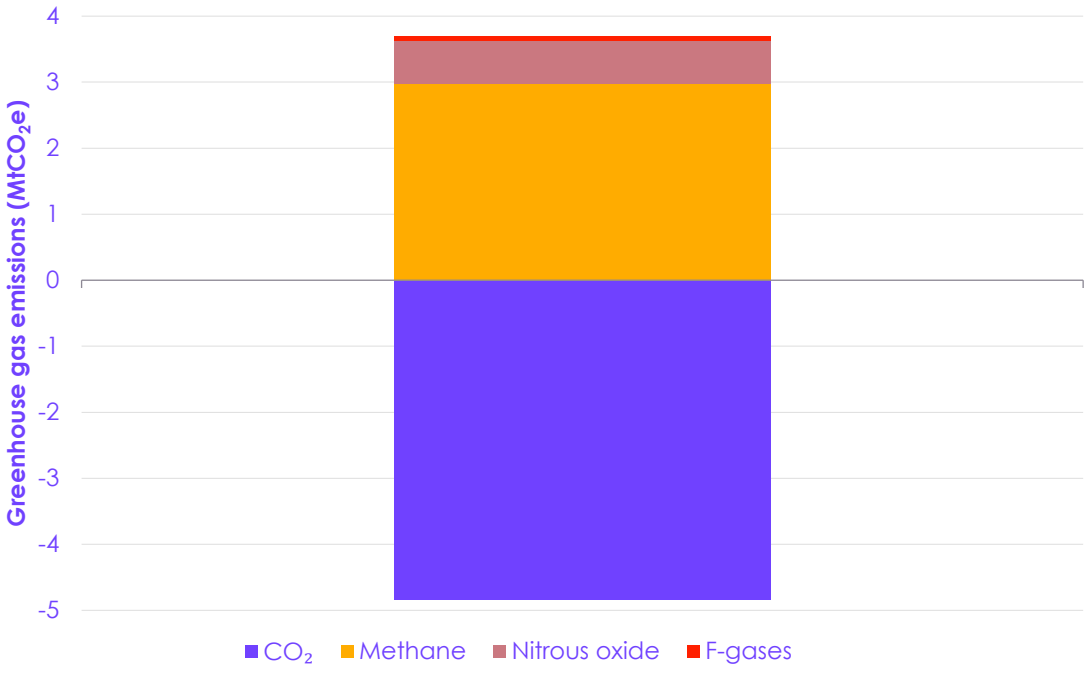
- The residual emissions that remain in Wales in 2050 are mostly methane (primarily from agriculture, with smaller contributions from land use and waste), which is a short-lived GHG. All remaining emissions will be balanced by removal of CO_2, which is much longer lived (Figure 2.7). Overall, this leads to a peak and then decline in Wales' contribution to global warming by 2050, as continuing shorter-lived methane emissions are offset by removals of long-lived CO_2.

Figure 2.6 Sources of emissions and negative emissions in the Balanced Pathway in 2050



Description: Net Zero is achieved by balancing remaining emissions from areas that cannot feasibly be decarbonised in our pathway with a combination of engineered and land-based removals. The land-based removals offset residual emissions from agriculture, while the engineered removals offset residual emissions from the remaining sectors.
Source: CCC analysis.

Figure 2.7 Emissions in the Balanced Pathway in 2050 by greenhouse gas



Description: The residual emissions that remain in Wales in 2050 are mostly methane (primarily from agriculture, with smaller contributions from land use and waste). All remaining emissions will be balanced by the removal of CO_2.
Source: CCC analysis.

2.5 Costs and investment in the Balanced Pathway

This section sets out the whole-economy costs and cost savings for Wales in the Balanced Pathway. More detail on the methodology behind this analysis can be found in Chapter 4 of the UK's Seventh Carbon Budget advice report.

Figure 2.8 shows the whole-economy costs for Wales between 2025 and 2050 under the Balanced Pathway. Costs are additional to a baseline of no further decarbonisation action and are presented undiscounted, in 2023 prices.[*]

- The pathway requires upfront investment, which generates operating cost savings. When combining capital and operating costs, we expect the pathway to generate a net cost for the whole economy of around £390 million per year between 2025 and 2050, which is around 0.4% of GDP.[†;1] The pathway becomes net saving from 2042.
  - **Additional capital (investment) cost is expected to peak in 2029** at £2.5 billion and is driven by deployment of low-carbon technologies and changes in their cost over time. We expect economies of scale and learning-by-doing to reduce low-carbon technology costs, slowing additional investment (and in some cases generating savings) towards 2050.
  - **Additional operating cost is negative throughout the 25-year period**, generating a cost saving relative to the baseline. Operating cost savings increasingly offset the investment costs required to meet the pathway, peaking at £1.7 billion in 2050.

At a sectoral level, costs follow a similar pattern to those for the UK as a whole. Key sector costs are discussed below:

- **Electricity supply:** the investment required to decarbonise the current electricity system is frontloaded in the 2020s and 2030s and becomes negative in the 2040s as the capital cost of renewables falls below the cost of gas generation in the baseline.
  - In the Balanced Pathway, the electricity system in Wales is also expanded to meet demand from the rest of Great Britain (GB). The GB cost profile is scaled to estimate costs required to decarbonise the current energy system, meeting Wales' demand only.[‡]
- **Residential buildings:** additional capital spending includes the upfront cost of low-carbon heating systems and energy efficiency improvements. These measures improve the efficiency of heating technologies, generating operating savings.

[*] Our baseline generally maintains the stock of low-carbon technologies that exist today (primarily renewable energy and EVs), making adjustments for GDP and population growth.

[†] GDP calculations use the latest ONS estimates of Wales' GDP in 2022, inflated to 2023 prices. This is likely to overstate the cost of the pathway relative to Wales' GDP in future years as GDP is likely to grow.

[‡] Electricity costs in Wales are determined by scaling down the cost of decarbonising the current GB system by Wales' share of GB electricity demand. The cost of expanding the system to meet additional electricity demand from other sectors (including residential buildings and surface transport) is counted in the operating costs of the sector which is using the energy.

- **Surface transport:** delivering the pathway for this sector results in cost savings from 2027. This is due to the falling cost of EVs compared to fossil fuel vehicles and increasing operating savings from improved efficiency and lower fuel and maintenance costs.

- **Agriculture and land use:** additional capital expenditure includes decarbonisation of machinery and investment into soil and livestock measures. For land use, capital and operating costs include woodland creation and management and peatland restoration.

- **Industry:** investment costs include the electrification of industrial processes (predominantly installing an electric arc furnace at Port Talbot), and hydrogen processes, with limited CCS.

- **Fuel supply:** costs in this sector are dominated by hydrogen supply, with smaller contributions from fossil fuel decarbonisation, bioenergy, and synthetic fuels.

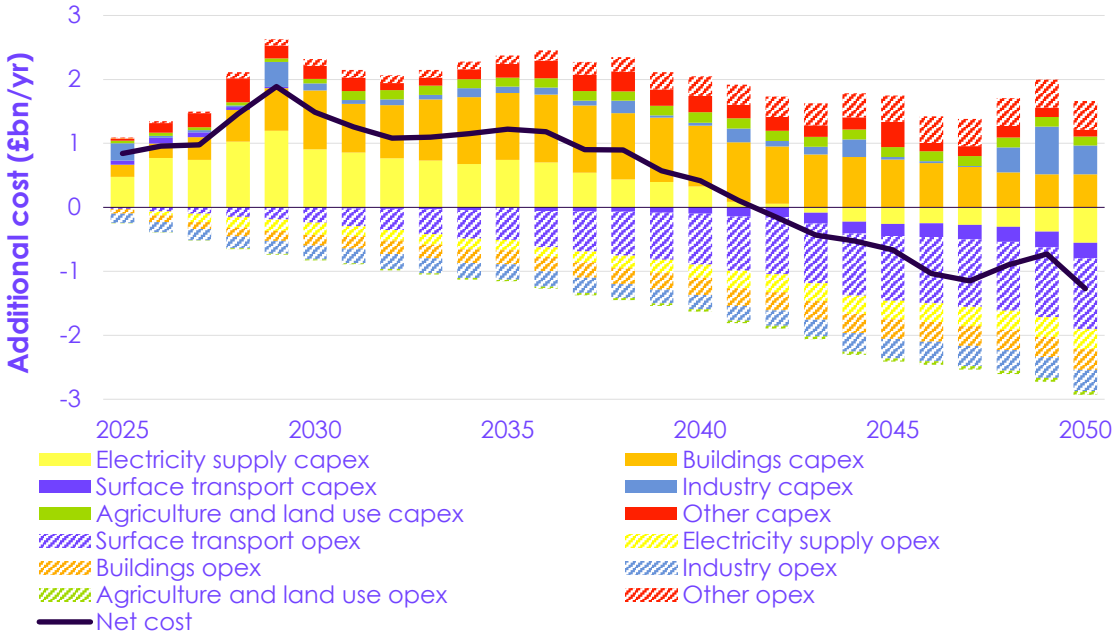
- **Engineered removals:** investment costs include production facilities for BECCS, DACCS, and biochar and enhanced weathering removals, and operating costs include maintenance and running costs for these facilities.

  - In practice, we assume the cost of engineered removals will be paid for by polluters.

- **Waste:** capital costs include CCS installation for the two EfW plants in Wales. Other costs include expenditure on landfill and recycling (including waste reduction measures) and wastewater improvements.

The economic cost of climate change impacts to Wales is highly uncertain and estimates vary depending on the extent of warming that takes place. However, if Wales and other countries fail to address climate change, the macroeconomic impacts on Wales could be high.

Figure 2.8 Additional costs and savings in the Balanced Pathway



Description: Additional costs in the Balanced Pathway are frontloaded, peaking in 2029. Capital costs are offset by operating savings in later years, with the pathway becoming a net cost saving overall in 2042.
Source: CCC analysis.
Notes: (1) In-year costs are in 2023 prices. (2) Capex is additional capital expenditure and opex is additional operating expenditure. Both are relative to a baseline of no further climate action. (3) The 'other' category includes fuel supply, engineered removals, waste, aviation, shipping, and F-gases. (4) Capex and opex are accounted for in the years of construction and operating respectively, aligning with Green Book practices. (5) In the aggregation of costs, we adjust for double counting by removing the cost of electricity and low-carbon fuels from the sectors which produce them and maintain this cost in sectors which consume them.

Endnotes

[1] Office for National Statistics (2024) *Regional gross domestic product: all ITL regions.* https://www.ons.gov.uk/economy/grossdomesticproductgdp/datasets/regionalgrossdomesticproductallnutslevelregions.

Chapter 3: Emissions reductions by sector in the Balanced Pathway

Introduction and key messages

This chapter describes the Balanced Pathway for Wales in each sector, setting out the key measures that combine to reduce emissions and the priority actions required to deliver the pathway.

Our key messages are:

- The start of Wales' Fourth Carbon Budget is only six years away. Achieving it will require a focus on key near-term actions and ensuring that the conditions are in place for these to be delivered.

- In the latest published emissions data, industry was the highest-emitting sector in Wales. But the closure of the blast furnaces at the Port Talbot steelworks means that, by the start of our pathway, it is expected to be fourth. Plans are proceeding to replace the blast furnaces with an electric arc furnace at Port Talbot by 2027. The handling of this transition is discussed in Chapter 4.

- Emissions in Wales are now likely to be dominated by agriculture, electricity supply, and surface transport, with important contributions from many other sectors. Decarbonising electricity supply provides around half the emissions reduction required over the Third Carbon Budget period. Contributions from surface transport, agriculture and land use, and buildings become increasingly important, together comprising more than 60% of the emissions reduction required over the Fourth Carbon Budget period.

    - Agriculture is projected to be Wales' highest-emitting sector throughout the pathway. The Welsh Government should urgently set out how the Sustainable Farming Scheme will support farmers to adopt low-carbon farming practices and to diversify their income streams to enable expansion of nature-based measures at the scale necessary.

    - In our pathway, by 2033 around one-third of cars and vans on Welsh roads are electric and nearly a quarter of existing homes in Wales have low-carbon electrified heating installed, predominantly heat pumps. More homes in Wales will be warmer and more comfortable with an increase in home insulation measures.

    - The switch to electric vehicles (EVs) and heat pumps and electrifying industry will result in demand for electricity increasing. To meet this growth and decarbonise the system, low-carbon generation needs to be rolled out quickly. Electricity networks will need to expand to enable consumers to benefit from reliable, low-cost, and low-carbon electricity.

3.1 Sectoral contributions

3.1.1 Emissions reductions by sector

Meeting the recommended Fourth Carbon Budget will require contributions across all sectors (Figure 3.1). In the Balanced Pathway, agriculture emissions fall but remain dominant. Emissions for the other main sectors will also fall. This will depend on switching to efficient, low-carbon technologies and reducing demand for high-carbon activities in a range of key areas.

- **Industry (emissions fall by 78% from 2022 to 2033).** Reductions in industry emissions predominantly come from electrification of industrial processes. The largest contribution to this comes from the closure of the blast furnaces at Port Talbot in 2024, and their expected replacement with an electric arc furnace (see Section 3.2.1).

- **Electricity supply (emissions fall by 85% from 2022 to 2033).** Electricity supply emissions are currently falling quickly, and this will need to continue. Further deployment of low-carbon generation technologies, such as wind and solar, is needed to decarbonise existing demand and meet new demand as other sectors electrify (see Section 3.2.2).

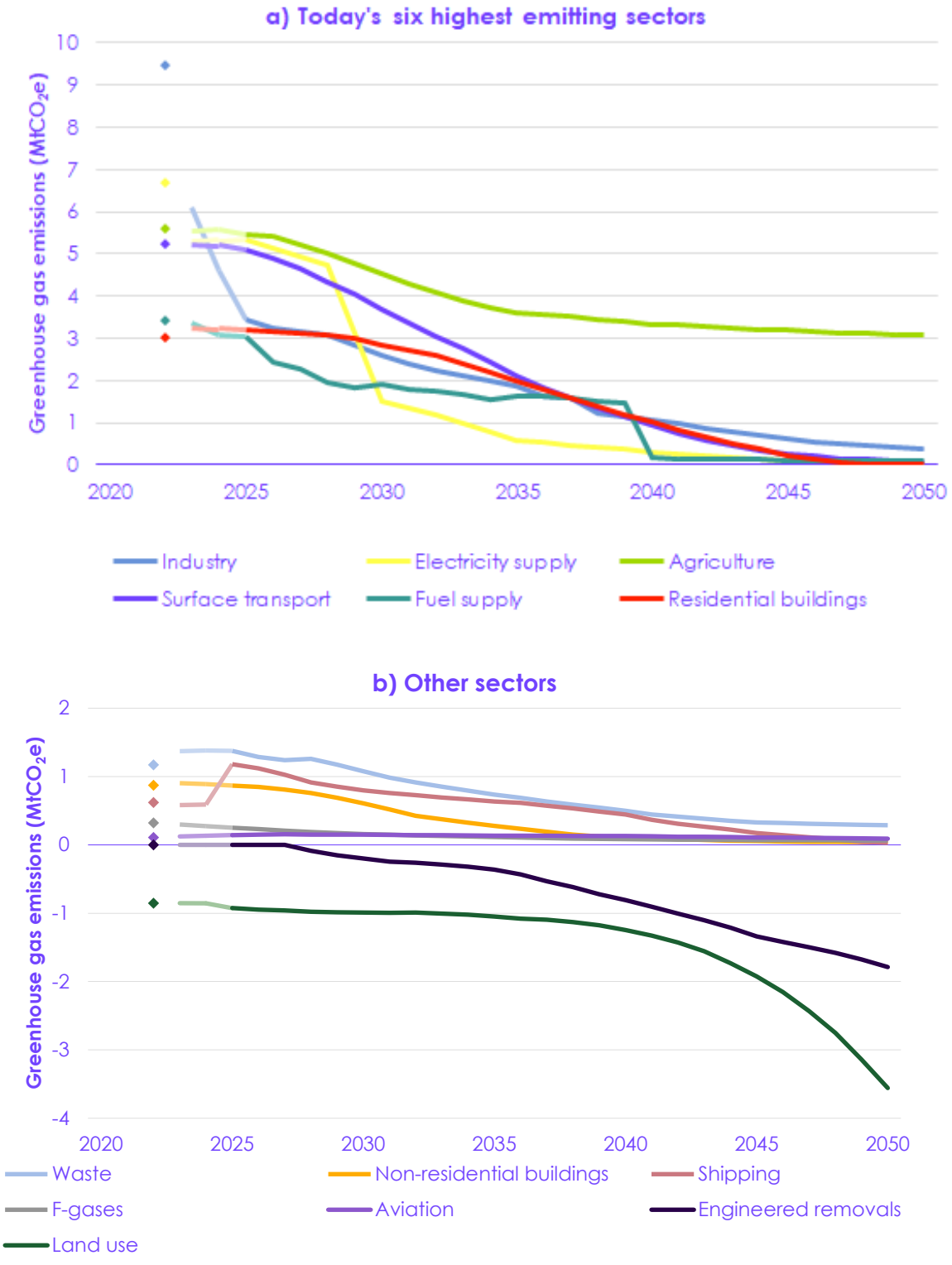
- **Agriculture and land use (emissions fall by 39% from 2022 to 2033).** Agriculture is expected to be the highest-emitting sector throughout the pathway. Emissions fall through a combination of low-carbon farming practices and technologies and a reduction in livestock numbers. The land use sector in Wales is currently a net emissions sink, and diversifying uses of land allows new woodlands to be created, further increasing carbon sequestration and offsetting residual agricultural emissions. By 2050, the combined agriculture and land use sectors are a slight net sink (see Section 3.2.3).

- **Surface transport (emissions fall by 48% from 2022 to 2033)**. The pathway for surface transport is primarily driven by the uptake of EVs, which we project to accelerate rapidly over the coming years as prices fall. Measures to enable a shift from car use to public transport and active travel also play a role in reducing emissions from fossil fuel vehicles, which will still make up the majority of the fleet during the Fourth Carbon Budget period (see Section 3.2.4).

- **Fuel supply (emissions fall by 52% from 2022 to 2033).** The largest share of emissions reduction in the fuel supply sector comes from reduced refinery output due to lower demand for petroleum products across the economy (see Section 3.2.5).

- **Residential buildings (emissions fall by 22% from 2022 to 2033).** The transition to low-carbon home heating (mostly heat pumps) will be ramping up by the Fourth Carbon Budget period. As most homes will still be heated using gas, however, the installation of home insulation measures also plays a significant role in reducing emissions (see Section 3.2.6).

Figure 3.1 Sectoral emissions in the Balanced Pathway



Description: Meeting the recommended Fourth Carbon Budget will require contributions across all sectors. In our Balanced Pathway, agriculture emissions fall but it remains the highest-emitting sector throughout the pathway. The emissions in all other sectors also fall. This will depend on switching to efficient, low-carbon technologies and reducing demand for high-carbon activities in a range of key areas.
Source: National Atmospheric Emissions Inventory (2024) Greenhouse Gas Inventories for England, Scotland, Wales & Northern Ireland: 1990-2022; CCC analysis.
Notes: (1) Our sectoral pathways are modelled using historical data up to 2022, shown with diamond-shaped markers in this chart. Projected emissions reductions prior to 2025 (shown in a pale shade in this chart) are based on existing trends; additional decarbonisation measures only begin from 2025. (2) Our pathway for shipping begins above the latest historical data mainly because, from 2025, we have based it on the Department for Transport's (DfT's) emissions model, which uses more recent activity data for domestic shipping and as a result gives a higher estimate of current shipping emissions than the GHG inventory. (3) The fall in fuel supply emissions in 2040 is driven by economy-wide fuel switching leading to a fall in production output from oil refineries.

3.1.2 Emissions reductions during each carbon budget period

Energy supply plays a significant role in meeting each of Wales' emissions targets. But the sectors that drive the rest of the reductions required will change between the first three carbon budgets, the Fourth Carbon Budget, and beyond (Figure 3.2). Action needs to broaden across a wider range of sectors to deliver the reductions that are required.

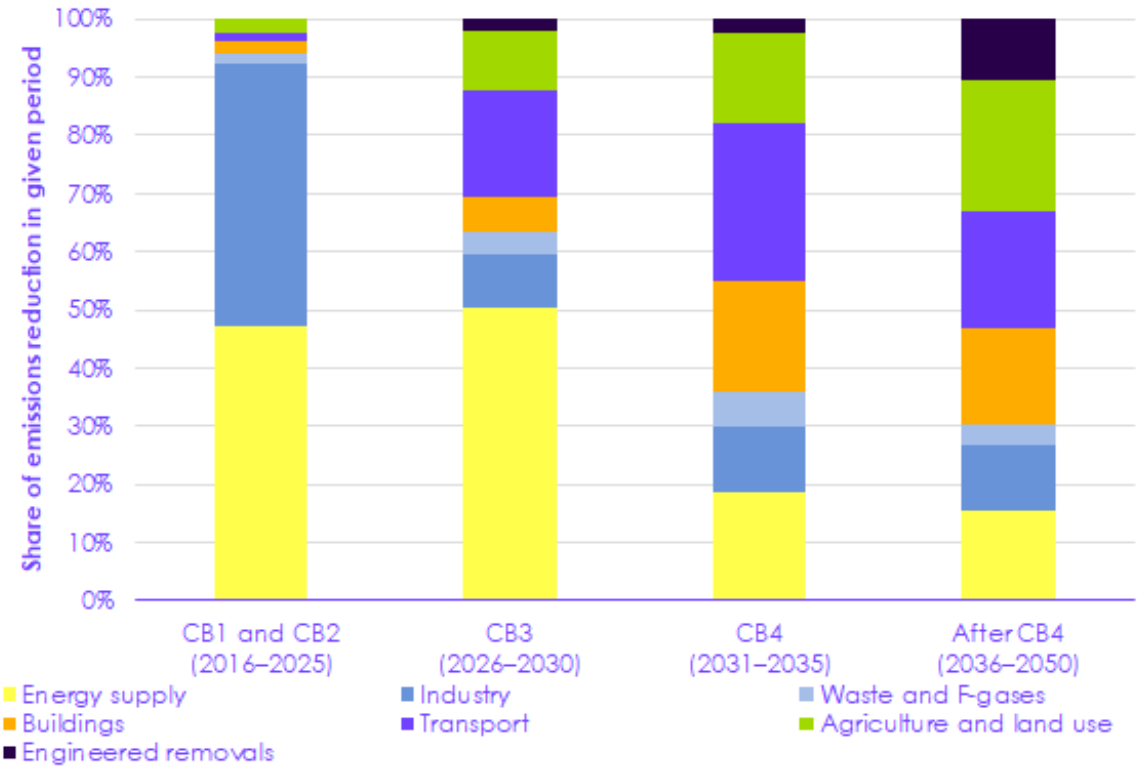
- Historically, over 90% of the emissions reduction (and projected emissions reductions for years for which data has not yet been published) during the First and Second Carbon Budget periods has come in the energy supply and industry sectors.

- Going forward, the rapid roll-out of low-carbon energy supply continues to play a significant role, delivering over half the emissions reduction required to meet the Third Carbon Budget. But around 35% of the required reduction will come from transport, agriculture and land use, and buildings. Focus now needs to shift to these sectors, which all have significant policy powers devolved to the Welsh Government.

- By the Fourth Carbon Budget period, more than 60% of emissions reduction will come in transport, buildings, and agriculture and land use.

- These sectors continue to make a large contribution in the years following the Fourth Carbon Budget period, as vehicle fleets and home heating electrify. Falling emissions in agriculture, increasing carbon sequestration in woodlands, and deployment of engineered removals play an important role in the final years of the pathway, helping reach Net Zero.

Figure 3.2 Distribution of emissions reductions during each carbon budget period in the Balanced Pathway for Wales



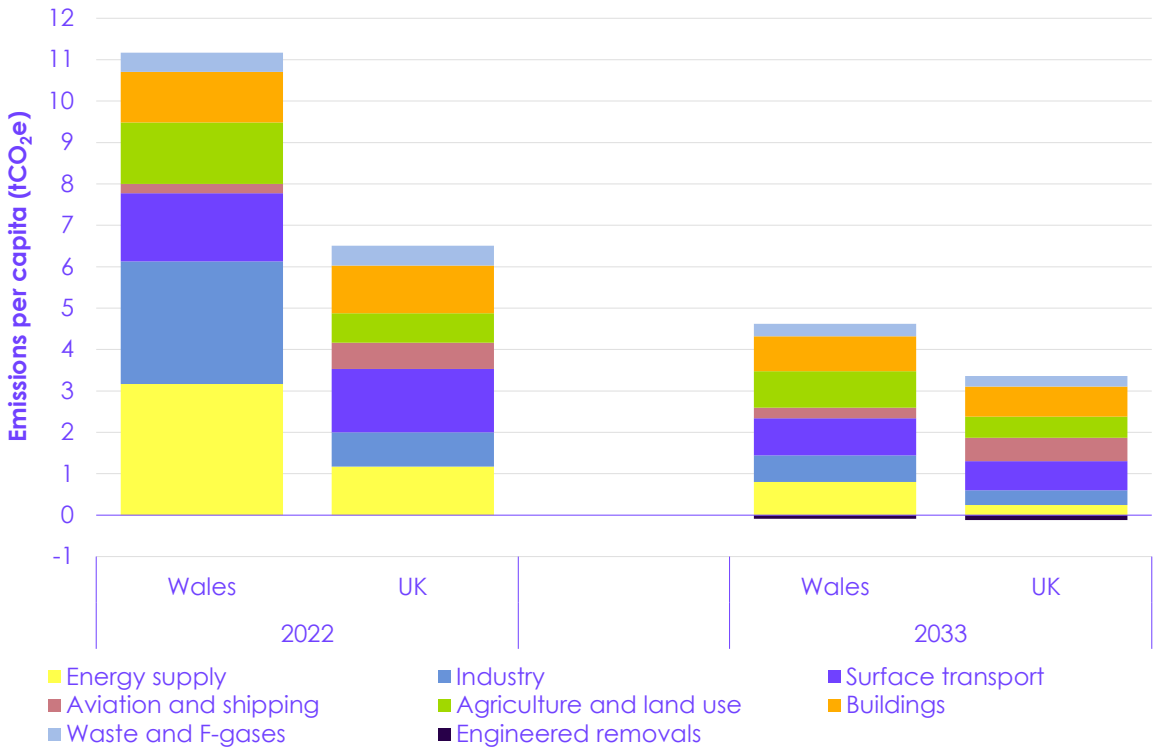
Description: Action to reduce emissions is needed across a wide range of sectors. While the vast majority of emissions reductions during the first two carbon budgets have come in the energy supply and industry sectors, increasing contributions from surface transport, agriculture and land use, and buildings will be required to meet the next two carbon budgets.
Source: Department for Energy Security and Net Zero (DESNZ) (2024) *Final UK greenhouse gas emissions national statistics: 1990 to 2022*; National Atmospheric Emissions Inventory (2024) *Greenhouse Gas Inventories for England, Scotland, Wales & Northern Ireland: 1990-2022*; CCC analysis.
Notes: We have grouped some sectors together to simplify the presentation in this chart, including transport, which is the combination of surface transport, aviation and shipping, and energy supply, which is the combination of electricity and fuel supply.

3.1.3 Emissions in Wales compared to the UK Balanced Pathway

Emissions in Wales made up 8% of 2022 UK emissions. On a per capita basis, emissions in Wales are nearly double those in the UK as a whole. By 2033, per capita emissions in Wales will have fallen by more than half and will be lower as a proportion of the UK-wide average than today (Figure 3.3).

- Per capita emissions in Wales in 2022 were driven by a high contribution from industry, which comprised 27% of Welsh emissions.
- Current per capita emissions are also higher in Wales than in the UK in several other sectors, including agriculture (due to Wales' relatively large agricultural sector) and energy supply (due to Wales producing a disproportionately large share of UK unabated gas power relative to electricity demand). Delivering the Balanced Pathway will result in Wales closing the emissions gap in these areas.
- The land use sector is currently a net sink in Wales, compared to a small net source in the UK as a whole. This slightly counteracts the larger contribution of agriculture to per capita Welsh emissions in Figure 3.3.
- Per capita aviation and shipping emissions are lower in Wales than the UK average. This is due to Wales' disproportionately low share of UK aviation emissions as many Welsh passengers take flights from English airports.

Figure 3.3 Emissions per capita in Wales and the UK – 2022 historical and 2033 in the Balanced Pathway



Description: On a per capita basis, emissions in Wales are nearly double those in the UK as a whole. By 2033, per capita emissions in Wales will have fallen by more than half and will be lower as a proportion of the UK-wide average than today.
Source: Department for Energy Security and Net Zero (DESNZ) (2024) Final UK greenhouse gas emissions national statistics: 1990 to 2022; CCC analysis.
Notes: We have grouped some sectors together to simplify the presentation in this chart, including energy supply, which is the combination of electricity supply and fuel supply.

3.2 The Balanced Pathway by sector

The following sections outline the Balanced Pathway by sector, summarising historical emissions trends in each sector, the key measures in each sector pathway, and key actions required to deliver the pathway. Delivery indicators for sectoral roll-outs of low-carbon technologies and land-based actions are shown in Figure 3.4 and for the demand for high-carbon activities in Figure 3.5. Where it is available, they are compared to historical data.

3.2.1 Industry

Emissions in industry

In 2022, industry was the highest-emitting sector in Wales, accounting for 27% of Wales' emissions.

Emissions in industry have fallen by 37% from 15.1 $MtCO_2e$ in 1990 to 9.5 $MtCO_2e$ in 2022.

- Industrial emissions in Wales have long been dominated by the iron and steel sector. Lower output from this sector is the main cause of the decline in emissions from 1990 to 2022. Lower emissions from the 'other manufacturing' sector has also been a significant driver of the reduction in industry emissions.[*;1]

- The blast furnaces at the Port Talbot steelworks closed in 2024. As the steelworks emitted 5.7 $MtCO_2e$ in 2023, Wales' industrial emissions will now have more than halved since 2022.[2] This leaves 'other manufacturing', cement, and non-metallic minerals as the largest sources of industrial emissions in Wales.[3]

  - Although the blast furnaces closed in 2024, their emissions are included in our baseline (which is based on emissions in 2022). Therefore, we attribute the costs, emissions reductions, and actions from the move to the electric arc furnace within our pathway.

The Balanced Pathway for industry

In our pathway, industry emissions fall by 78% from 9.5 $MtCO_2e$ in 2022 to 2.1 $MtCO_2e$ by 2033 (the midpoint of the Fourth Carbon Budget period).

The key measures that combine to reduce emissions in industry are:

- **Electrification (91% of emissions reduction in 2033).** This is the most important measure in our industry pathway and relates to more extensive use of electricity for heat processes.

  - There is growing recognition that electrification of heat should be the main route to decarbonising industry.[4] There are electric alternatives to most types of fossil fuel-fired heating equipment used in industry.

  - The proportion of industrial energy supplied by electricity rises from 13% in 2022 to 30% by 2033 (Figure 3.4a).

  - Most abatement from electrification is at the Port Talbot steelworks, where we assume an electric arc furnace is installed. We discuss the handling of the Port Talbot steelworks transition in Box 4.1 in Chapter 4.

[*] 'Other manufacturing' includes, for example, manufacturing of consumer products and machinery and equipment.

- **Resource efficiency and energy efficiency (5% of emissions reduction in 2033).** Using energy more efficiently reduces operating costs while cutting emissions. Demand for materials can be reduced by material switching, reducing consumption, and producing goods with fewer material inputs.

- **Fuel switching (bioenergy 3%; hydrogen 1% of emissions reduction in 2033).** Most gas-fired industrial processes could in principle be converted to run on either bioenergy or hydrogen. In our pathway, the largest role for bioenergy is in the non-road mobile machinery subsector, while the most important role for hydrogen is in the iron and steel subsector (for hot rolling).

- **Carbon capture and storage (CCS).** CCS is needed for tackling industrial process emissions. CCS makes only a very small contribution to emissions reduction by 2033 as we assume the South Wales Industrial Cluster does not become operational until that year. By 2050, CCS contributes to 0.3 $MtCO_2e$ of emissions reduction in industry, largely in the cement sector.

Key actions to deliver the Balanced Pathway in industry

Policy in the industry sector is largely reserved. The key recommended actions for the Welsh Government are as follows:

- Work with the UK Government to enable industrial decarbonisation in Wales, including by speeding up grid connections and planning processes, and establishing ambitious transition plans for communities which host significant emissions-intensive industrial facilities.

  - In particular, the Welsh Government should support the development of plans to develop CCS and hydrogen in the South Wales Industrial Cluster and the HyNet cluster (which will support decarbonisation of some industrial sites in Wales).

- Define the skills and workforce requirements for low-carbon manufacturing in Wales, and develop policies to deliver them.

- Ensure businesses have access to appropriate information and support to reduce their emissions.

3.2.2 Electricity supply

Emissions in electricity supply

In 2022, electricity supply was the second highest-emitting sector in Wales, accounting for 19% of Wales' emissions.

Emissions in electricity supply have fallen by 40% from 11.2 $MtCO_2e$ in 1990 to 6.7 $MtCO_2e$ in 2022.

- Coal generation has been completely phased out of the generation mix in Wales. The drop in Wales' emissions between 1990 and 1995 was largely due to the temporary closure of Uskmouth B coal power station, which reopened in 2000 (see Figure 1.4).[5;6]

- Emissions peaked in 2013 at 16.1 $MtCO_2e$. Between 2013 and 2022, emissions fell by 58%. The share of coal generation in Wales in 2013 was 29% but began to rapidly fall following the introduction of policies including the Carbon Price Floor and the Industrial Emissions Directive. The last remaining coal plant in Wales, Aberthaw, closed in 2020.[7]

- The share of generation from variable renewables has increased from 3% in 2004 to 22% in 2022, displacing generation from coal and gas.

- Demand for electricity has been falling by around 1% per year since 2015.

The Balanced Pathway for electricity supply

In our pathway, electricity supply emissions fall by 85% from 6.7 $MtCO_2e$ in 2022 to 1.0 $MtCO_2e$ by 2033.

Our modelling approach is consistent with our electricity system modelling for our advice on the UK's Seventh Carbon Budget, and models the electricity system at plant level on an hourly basis out to 2050. We have dimensioned the modelled electricity system to be resilient at the 20-year return period (that is, to a 1-in-20 adverse weather year). Emissions, generation, and variable costs are based on the weather corresponding to an average emissions year.

The key elements of the future electricity supply system in our pathway are:

- **Electricity demand.** Annual electricity demand increases from 16 TWh in 2022 to 19 TWh by 2033. This reflects the increasing electrification of transport, buildings, and industry.
- **Variable renewables (78% of generation in 2033).*** Renewables have an essential role to play in achieving the Fourth Carbon Budget and meeting the vast majority of demand.
  - In our pathway, variable renewables capacity increases from 3.4 GW in 2022 to 8.0 GW by 2033, including a mix of offshore wind, onshore wind, and solar.
  - This capacity provides 18 TWh of renewable generation in 2033 (Figure 3.4b).
- **Dispatchable generation (17% of generation in 2033).** This refers to sources of generation that can be planned with a high degree of confidence to provide flexible, controllable electricity. Dispatchable generation will be required to provide security of supply, particularly during periods of low production from variable, weather-dependent renewables.
  - **Low-carbon dispatchable generation.** Our pathway sees the development of CCS and hydrogen infrastructure enabling the deployment of low-carbon dispatchable generation (for example, gas with CCS or hydrogen-fired turbines). Capacity reaches 0.4 GW by 2033 (Figure 3.4c).
  - **Unabated gas.** Our pathway rapidly phases out the use of unabated gas generation, with its occasional use acting to balance the system and ensure security of supply. Our pathway therefore maintains a reserve of unabated gas capacity into at least the 2040s, with its use phased out by 2050.
- **Firm power (5% of generation in 2033).** This refers to sources of predictable and schedulable electricity generation with relatively inflexible generation profiles.
  - **Bioenergy, energy from waste (EfW), and combined heat and power (CHP).** Firm power generation in the Fourth Carbon Budget period is from existing small-scale bioenergy, EfW, and CHP plants. Electricity generation from unabated bioenergy is not a best use of bioenergy resources, and as such we gradually phase its use out, with no role for unabated biomass by 2037. CCS is installed at EfW plants in Wales (see Section 3.2.7).
  - **Nuclear.** There is currently no nuclear capacity in Wales. Our pathway includes 1.6 GW of nuclear capacity in the 2040s, which could be delivered with large-scale projects or small modular reactors. However, the location of new nuclear projects will be a commercial decision for developers.

* In 2033, around 4 TWh of generation in Wales is exported to the Republic of Ireland and the rest of the UK.

- **Grid storage (2.4 GW / 11 GWh in 2033).** With an increasing share of variable renewables, grid storage such as batteries can capture energy, typically when it is cheap, to provide electricity in periods when demand is higher and electricity is more valuable. It can operate on short-to-medium timescales to provide flexibility when it is most valuable.

- **Networks and interconnection.** The capacity of transmission and distribution networks will need to be increased at pace to ensure supply is able to be transported to sources of demand as electricity generation is increasingly decarbonised and demand grows. Connection of the electricity grid to neighbouring markets enables imports of electricity when it is cheaper to do so and provides a market for surplus generation. In our pathway, Wales remains a net exporter of electricity to the Republic of Ireland and the rest of the UK.

Key actions to deliver the Balanced Pathway in electricity supply

Policy in the electricity supply sector is largely reserved. Wales is part of the Great Britain-wide electricity system. Decisions on nationally significant energy infrastructure projects are taken in line with the National Policy Statements for energy infrastructure. The key recommended actions for the Welsh Government are as follows:

- Deployment of low-carbon generation and associated infrastructure is required at scale in Wales. The Welsh Government must work with the UK Government to deliver strong policy consistent with decarbonising electricity supply in Wales (for example, on standards for new-build power plants), and to continue to progress Welsh-specific programmes where these are devolved (for example, on planning and consenting for new low-carbon developments).

3.2.3 Agriculture and land use

Combined emissions in the agriculture and land use sectors were 4.7 $MtCO_2e$ in 2022. This is 17% lower than 1990, when emissions totalled 5.7 $MtCO_2e$.

Emissions in agriculture

In 2022, agriculture was the third highest-emitting sector in Wales, accounting for 16% of Wales' emissions.

Emissions in agriculture have decreased by 8% from 6.1 $MtCO_2e$ in 1990 to 5.6 $MtCO_2e$ in 2022.

- Livestock emissions from enteric fermentation (the digestive process of cattle and sheep) and waste and manure management declined by 5% to 4.5 $MtCO_2e$. This is probably due to a decrease in cattle and sheep numbers respectively over the period.

- Soils emissions decreased by 46% to 0.5 $MtCO_2e$ due to a sharp drop (48%) in the average application rate of nitrogen fertiliser. While more efficient use of fertiliser has reduced application rates since 1990, rates hit a historic low in 2022.[8] This was due to rising fertiliser costs associated with the increased price of natural gas (used in the production of fertilisers) attributed to Russia's invasion of Ukraine.[9] Levels have since rebounded in 2023 but remain below pre-2022 levels.

In 2022, land use was a net sink of -0.9 $MtCO_2e$. Land use has been a net sink of emissions since 1990, when it was -0.4 $MtCO_2e$.

- Much of this increase in the land sink occurred in the 2000s, with net negative emissions remaining fairly level over the 2010s.

- Land use is a net sink largely due to the forestry subsector, which was a sink of 1.5 $MtCO_2e$ in 2022. The forestry sink in Wales shows a trend of declining since a peak sink of around -1.8 $MtCO_2e$ was achieved in the late 2000s.

- Grasslands on mineral soils are also a significant sink in Wales, at -0.6 $MtCO_2e$ in 2022. This has increased very slightly since 1990.

- The largest source of land use emissions is from cropland, which had emissions of 0.7 $MtCO_2e$ in 2022. However, this has decreased by 0.4 $MtCO_2e$ since 1990, mainly due to reduced emissions from grassland land use change to cropland over this period.

- Other land use emissions sources include peatland (0.3 $MtCO_2e$) and settlements (0.3 $MtCO_2e$). Emissions from these subsectors have fallen by 0.1 and 0.3 $MtCO_2e$ respectively since 1990.

The Balanced Pathway for agriculture and land use

By 2033, combined emissions for agriculture and land use are projected to fall by 39% to 2.9 $MtCO_2e$ in the Balanced Pathway. This continues to fall, with the combined sectors reaching 0.5 $MtCO_2e$ by 2050.

Agriculture

In our pathway, agriculture emissions fall by 30% from 4.7 $MtCO_2e$ in 2022 to 3.9 $MtCO_2e$ by 2033.

The key measures that combine to reduce emissions in agriculture are:

- **Low-carbon farming practices and technologies (51% of emissions reduction in 2033).** The take-up of on-farm practices and technologies combine to reduce emissions from managing agricultural soils and livestock and from machinery use.

  - **Soils and livestock measures (31% of emissions reduction in 2033).** The 29 measures that we have identified target livestock emissions (for example, feed additives to inhibit methane in cattle, breeding and livestock health measures to reduce emissions intensity, and better management of animal waste) and emissions from soils.

    - The largest group of savings are delivered by measures for livestock feed and the reduction of fertiliser use on soils, mainly grassland (for example, grass-legume mix), with each delivering around a quarter of the abatement in 2033.

    - Waste and manure management measures account for a further 20% of emissions savings.

  - **Decarbonising machinery (20% of emissions reduction in 2033).** Energy use emissions decline in line with the fall in livestock numbers and agricultural land area due to the land-release measures cited below. Machinery is electrified except for larger off-road mobile machinery, which switches to hydrogen. Should technology develop, however, then electrification could be used to decarbonise the whole fleet. Bioenergy is used as a transitional fuel but phased out by 2040.

- **Reducing livestock numbers (47% of emissions reduction in 2033).** Cattle and sheep numbers fall by 19% by 2033 compared to 2022 (Figure 3.5a) due to changes in agricultural policy that enable livestock farmers to diversify income streams; a shift in UK-wide consumption towards lower-carbon foods, with average meat, red meat, and dairy consumption falling by 16%, 21%, and 17% respectively by 2033 compared to 2019 (Figure 3.5b), which is in line with our UK Balanced Pathway; and improvements in productivity from

livestock measures (for example, improving livestock health and robotic milking parlours) that reduce methane and nitrous oxide.

  - This reduction in meat consumption requires going beyond the existing UK long-term trend, which shows a gradual fall in consumption. In recent years, meat purchases have fallen more steeply, with a 10% fall in overall meat consumption between 2020 and 2022. This represents a faster rate of decline than in our pathway (Figure 3.5b).[10] It is too early to tell whether this steeper-than-projected trend will continue in the long term or is a temporary response to the cost-of-living crisis, which saw an 11% decrease in overall UK food purchases by weight between 2020 and 2022.[11]

  - Most beef and sheep meat produced in Wales is exported, with the domestic market accounting for around 5% of sales in 2021. The rest of the UK is the largest market, accounting for 80% and 60% of sales of beef and sheep meat respectively.[12]

- **Four further measures (2% of emissions reduction in 2033).** These are sustainable improvements in crop yields, reducing food waste, shifting some horticultural production to indoor systems, and nitrous oxide savings from the restoration and sustainable management of lowland cropland on peat.*

Land use

In our pathway, land use emissions fall from -0.9 $MtCO_2e$ in 2022 to -1.0 $MtCO_2e$ by 2033, and to -3.7 $MtCO_2e$ by 2050

The key measures that combine to reduce emissions in the land use sector are:

- **Woodland creation and management (57% of emissions reduction in 2033; 72% in 2050).** Woodland measures offer the largest share of emissions reduction in the land use sector. There is a delay between the planting of woodlands and the time it takes for them to reach peak sequestration rates. New woodlands planted post 2025 become a net sink in the early 2040s and by 2050 offer emissions reduction of 1.0 $MtCO_2e$.

  - Woodland creation rates rise from around 1,200 hectares per year in 2025 to reach peak rates of 9,800 hectares per year by 2036.† The proportion of woodland cover rises from the current 15% to 17% in 2033, and 26% by 2050 (Figure 3.4d).

  - The Welsh Government has articulated ambition to create 43,000 hectares of new woodland by 2030, rising to 180,000 hectares by 2050.[13] The Balanced Pathway ambition would result in achieving 22,000 hectares by 2030, and 208,000 hectares by 2050, including 15% of open ground for biodiversity.

  - While achieving 26% woodland cover is higher than the UK-wide ambition, it reflects the suitability of land for this action and lower rates of change in other land measures in Wales in our pathway (for example, peatland restoration and energy crops). Overall, land use change to new measures is comparable with the UK proportional change at 14%.

* Nitrous oxide emissions from lowland cropland peat are reported in the GHG inventory for the agricultural sector. Methane and CO_2 emissions on this type of peatland are reported in the land use, land use change and forestry (LULUCF) sector in the inventory.

† This peak planting area includes the 15% additional area of open ground.

- **Peatland restoration and management (12% of emissions reduction in 2033; 7% in 2050).** The rewetting and restoration of degraded peatlands offers emissions reduction of 0.02 $MtCO_2e$ by 2033, increasing to 0.1 $MtCO_2e$ by 2050. This is largely due to restoration activities on upland peatlands.

  - The proportion of peat under restoration and rewetting management increases from the current 41% to 52% in 2033, and to 85% by 2050 (Figure 3.4e).

- **Agroforestry and hedgerows (31% of emissions reduction in 2033; 21% in 2050).** Increasing trees and hedges on farms supports continued food production alongside sequestration in vegetation and soils. These actions provide 0.05 $MtCO_2e$ of emissions reduction by 2033, rising to 0.4 $MtCO_2e$ by 2050. We assume the transition to agroforestry rises annually by 760 hectares.

Perennial energy crops are not represented in the Balanced Pathway in Wales due to the lack of appropriate land for planting and the infrastructure constraints in utilising the crop when harvested. However, it is expected there will be opportunities at a site-level for land managers to incorporate these crops into their operations, either where the crop is transportable for use as bioenergy, or for alternative uses. This will provide carbon sequestration opportunities in addition to those described above.

Key actions to deliver the Balanced Pathway in agriculture and land use

Policy in the agriculture and land use sectors is largely devolved. The key recommended actions for the Welsh Government are as follows:

- Provide long-term certainty on public funding for farming practices and technologies to reduce emissions from managing crops and livestock. As part of this, ensure low-regret and low-cost measures are taken up through baseline regulations or minimum requirements in agricultural support mechanisms, especially when they can deliver efficiency improvements.

- Support a shift in average meat and dairy consumption towards lower-carbon foods. The most promising levers include replacing a small amount of meat and dairy content in pre-prepared meals with plant whole foods or alternative proteins; increasing choice and availability of lower-carbon foods in public procurement, restaurants, and supermarkets; and supporting novel alternative proteins with improved taste and texture.

- Provide incentives and address barriers for farmers and land managers to diversify land use and management into woodland creation, peatland restoration, agroforestry, and renewable energy. These policies need to support and empower rural communities to deliver these changes.

3.2.4 Surface transport

Emissions in surface transport

In 2022, surface transport was the fourth highest-emitting sector in Wales, accounting for 15% of Wales' emissions.

Emissions in surface transport have decreased by 6% from 5.6 $MtCO_2e$ in 1990 to 5.3 $MtCO_2e$ in 2022.

- The COVID-19 pandemic caused a drop in emissions during 2020. While emissions have partially rebounded since then, they remain approximately 10% below 2019 levels due to sustained shifts in travel patterns and working from home.

- EVs are becoming more established in Wales, with around 19,700 electric cars on the roads in Wales in 2023 making up 1.2% of the car fleet, less than half the UK average of 2.8%.[14] Electric vans made up 0.6% of the van fleet in 2023.[15;16]

- Wales' network of public chargers grew to around 2,250 in 2023, a 53% increase from 2022.*;[17]

The Balanced Pathway for surface transport

In our pathway, surface transport emissions fall by 48% from 5.3 $MtCO_2e$ in 2022 to 2.7 $MtCO_2e$ in 2033.

The key measures that combine to reduce emissions in surface transport are:

- **Electric cars and vans (54% and 20% respectively of emissions reduction in 2033).** By 2033, 39% of cars (Figure 3.4f) and 37% of vans on the road are electric. New electric car and van sales are expected to reach 90% of total sales in 2030. Although this is behind the 95% market share in the UK's Seventh Carbon Budget advice, Wales is projected to catch up with the UK Balanced Pathway and meet 100% of new sales by 2035.

  - In 2023, the market share of new electric cars in Wales was 8%, compared to an overall UK level of 16%.[18] Our pathway sees sales of new electric cars reach 89% of the market in Wales by 2030.

  - EV uptake is driven largely by the decreasing cost of electric cars which are expected to reach upfront purchase price parity with petrol cars between 2026 and 2028, depending on vehicle size.

  - Sales of new electric vans in Wales were 2% of the market in 2023, compared to a UK market share of 6%.[19] Our pathway sees sales of new electric vans exceed the ZEV mandate in Wales from 2028, reaching 55% of the market, with 100% of new vans sold being electric by 2030.

  - Cars and vans in Wales are on average four and 18 months older, respectively, than the UK average.[20] This means that vehicles stay in the fleet for longer, so it takes longer to replace the fleet than the UK. This results in a slightly slower rate of decarbonisation of the sector in Wales. It also indicates that used cars make up a greater share of the market in Wales compared to the UK as a whole, but over time that market will be increasingly made up of EVs.

  - Public EV charge points per capita in Wales are similar to the UK average.[21] The Welsh Government's EV charging strategy aims to deploy at least 30,000 fast chargers by 2030, which will significantly support the growth in EV sales required in our pathway.[22]

- **Zero-emission HGVs (3% of emissions reduction in 2033).** Our pathway assumes battery-electric vehicles are the option chosen to decarbonise all heavy goods vehicles (HGVs). However, there is still some uncertainty regarding the exact make-up of technologies in the fleet that will meet requirements for specific long-distance journeys or for particularly heavy cargoes.

  - While market development is at an earlier stage for electric HGVs than cars and vans, manufacturers are beginning to launch new models. Roll-out in our pathway scales up from the late-2020s, with 17% of HGVs on the road being electric by 2033.

* Charge point numbers for 2022 and 2023 are based on data from January 2023 and January 2024 respectively.

- The UK Government's commitment to end sales of new fossil fuel HGVs across the UK by 2040 (2035 for smaller HGVs) sends a strong signal to industry to invest in zero-emission HGVs.

- **Modal shift and efficient driving (15% of emissions reduction in 2033).** Improvements to make buses and active travel more attractive, affordable, and accessible allow 6% of baseline car demand (measured in car-kilometres) to switch to public transport and active travel by 2033, rising to 7% by 2035 which is maintained to 2050. While car-kilometres continue to grow, modal shift reduces the growth rate compared to the baseline. The actual reduction depends on potential rebound effects, as EV owners may drive more due to lower operating costs (Figure 3.5c).

  - We assume a 6% shift in car-kilometres to public transport and active travel in Wales by 2033. This is informed by evidence on successful public transport and active travel interventions in countries such as Germany and the Netherlands and in selected towns and cities in England and Scotland, as well as the urban/rural population distribution of Wales.[23;24]

  - The Welsh Government has aims to increase the proportion of journeys by public transport, walking, and cycling from the current estimated 27% to 33% by 2030 and at least 35% by 2040 – however, these targets cannot be directly compared to the ambition for demand reduction in our pathway.[25]

  - We also assume small improvements in average driving efficiency through improved speed limit compliance and eco-driving training for HGV drivers.

- **Conventional vehicle efficiency, other zero-emission vehicles and rail decarbonisation (5%, 2% and 1% of emissions reduction in 2033, respectively).**

  - While EV sales are growing, it is important to reduce the CO_2 intensities of conventional vehicles still being sold. This is achieved through fuel efficiency improvements to petrol and diesel vehicles, including measures such as light-weighting and hybridisation. We also assume size distributions of new cars will be maintained at current levels - ending recent trends towards larger vehicles. Our pathway also assumes continued blending of biofuels, with some increase in blending rates of biodiesel, predominantly used in HGVs and vans.

  - We assume other vehicles such as buses and coaches continue to switch to zero-emission technologies. The Welsh Government plans to convert the entire medium- to long-range Traws Cymru bus network to zero-emission vehicles by 2026, with a broader goal of achieving a fully zero-emission bus fleet across all services by 2035, which goes further than the ambition of our pathway.[26] In our pathway, we assume that 37% of the bus fleet in Wales is electric in 2035, and these buses drive half of all bus-kilometres. Local routes will be largely served by battery-electric vehicles. Long-distance routes and coaches face similar challenges to HGVs, so electrify more slowly.

  - Rail travel is further decarbonised by increasing electrification of the network, along with a small role for hydrogen-powered and battery-electric trains in the medium term. Transport for Wales recently introduced the UK's first tri-mode trains that can run on electric, diesel, or battery power, with 14 units being delivered for use by spring 2025.[27]

Key actions to deliver the Balanced Pathway in surface transport

Policy in the surface transport sector is largely devolved, including key enablers of the EV transition such as charging infrastructure as well as devolved responsibilities over roads and public transport. Implementation of the UK-wide ZEV mandate is the most significant policy priority for decarbonising surface transport. The key recommended actions for the Welsh Government are as follows:

- Support successful implementation of the ZEV mandate. The Welsh Government has an important role in enabling this, for example by expanding provision of charging infrastructure and providing reliable public information.
  - This includes ensuring suitable planning policies and funding models are in place to support the development of charging infrastructure, including on key freight routes.
  - The Welsh Government, local councils and industry also have a role in providing reliable information on the benefits of EVs to help counter public misconceptions.[28]
- The Welsh Government should consider further policies and incentives to accelerate zero-emission van uptake, working with major van fleet operators to understand and overcome barriers to uptake such as charging and access to finance.
- The Welsh Government should deliver its modal shift ambitions by improving public transport services and active travel infrastructure through strategic investment in integrated networks, enhanced services, and dedicated walking and cycling routes, supported by long-term funding and powers for local councils.

3.2.5 Fuel supply

Emissions in fuel supply

In 2022, fuel supply was the fifth highest emitting sector in Wales, accounting for 10% of Wales' emissions.

Emissions in fuel supply have fallen by 48% from 6.6 $MtCO_2e$ in 1990 to 3.4 $MtCO_2e$ in 2022.

- Oil refining contributed the majority (70%) of emissions, emitting 2.4 $MtCO_2e$ in 2022. These emissions have fallen 32% between 1990 and 2022, with the closure of Milford Haven refinery in 2014 reducing refining emissions between 2013 and 2014 in Wales by 1.0 $MtCO_2e$.
- Oil and gas production emissions have averaged around 0.4 $MtCO_2e$ for the past decade, including in 2022.
- Emissions from coal production have fallen 86% between 1990 and 2022, emitting 0.3 $MtCO_2e$ in 2022.

The Balanced Pathway for fuel supply

In our pathway, fuel supply emissions fall by 52% from 3.4 $MtCO_2e$ in 2022 to 1.7 $MtCO_2e$ by 2033.

From the baseline, first we account for significant changes across the economy that would affect demand. Decreased use of oil, largely due to the uptake of EVs in surface transport, leads to reductions in demand for oil refineries which reduces remaining refining production.

- **Fuel switching (49% of emissions reduction in 2033).** This is the largest contributor to reducing emissions in the fuel supply pathway, abating 0.6 $MtCO_2e$ in 2033.

Then the key decarbonisation measures that combine to address fossil fuel production emissions are:

- **Reduced methane leakage (29% of emissions reduction in 2033).** Gas leaks from the gas network are reduced by applying leakage detection measures.

- **Electrification (23% of emissions reduction in 2033).** Generators and compressors are electrified on over half of existing offshore oil and gas platforms and terminals in the Irish Sea.

For low-carbon fuel production, we use a mix of in-house modelling and hourly optimised electricity system modelling to determine the level of bioenergy, hydrogen, and synthetic fuel supply required to meet cross-economy sector demands. There are small initial deployments of low-carbon fuels by the time of the Fourth Carbon Budget, but their roles increase later in the pathway to 2050.

- **Bioenergy**: in 2033, just over 4 TWh of bioenergy resource is available in Wales, mostly biomass and dry bio-wastes. These are considered best used to deliver emissions savings, primarily in EfW plants with CCS.

- **Low-carbon hydrogen:** 0.2 TWh of hydrogen is available in 2033 from the South Wales Industrial Cluster. Capacity reaches 37 MW by 2033 and is predominantly produced via electrolysis using surplus zero-carbon electricity generation.

- **Synthetic fuels**: defined as fuels produced using hydrogen and a source of CO_2 recovered from the atmosphere (via direct air capture, for example). They are liquid hydrocarbons that can directly replace fossil fuels in jet engines and shipping vessels.

  - A mix of bio-based and synthetic jet fuels meet 10% of fuel demand from Welsh flights in 2033.

  - International emissions accounting rules for synthetic fuels are currently unclear.[29] They could require emissions savings for captured carbon to be counted in the country where the capture takes place. This would mean emissions savings from synthetic fuels are counted in the producing country, not the place of fuel combustion (this does not apply to other low-carbon fuels that are not based on captured carbon, including biofuels and hydrogen).

  - In line with our Balanced Pathway for the UK, we have conservatively assumed that all synthetic fuel used in Wales is produced domestically to meet demand, enabling the emissions savings to contribute to Welsh emissions reductions.

Key actions to deliver the Balanced Pathway in fuel supply

Policy in the fuel supply sector is largely reserved. The key recommended actions for the Welsh Government are to work with the UK Government to:

- Assess the potential for large-scale hydrogen production and infrastructure in Wales, and how Wales can best contribute to UK-wide hydrogen plans.

- Clarify the Welsh Government's position on bioenergy, setting out its best use, key delivery mechanisms, and future timelines for developing a sustainable bioenergy market.

- Develop proactive transition plans that enable access to secure employment and business opportunities for communities, workers, and businesses in the oil and gas industry. These efforts should feed into local or regional plans.

3.2.6 Residential buildings

Emissions in residential buildings

In 2022, residential buildings was the sixth highest-emitting sector in Wales, accounting for 8% of Wales' emissions.

Emissions from residential buildings have fallen by 39% from 5.0 $MtCO_2e$ in 1990 to 3.0 $MtCO_2e$ in 2022.

- The majority of homes (91%) in Wales are still heated using fossil fuels.[30]
- Policies have helped to improve the efficiency of heating technologies and deliver investments in building fabric efficiency.[31;32]
- Emissions have fallen since 2021, driven by high energy prices and mild winters.

The Balanced Pathway for residential buildings

In our pathway, emissions from residential buildings fall by 22% from 3.0 $MtCO_2e$ in 2022 to 2.4 $MtCO_2e$ by 2033.

The key measures that combine to reduce emissions in residential buildings are:

- **Low-carbon heating (43% of emissions reduction in 2033).** Low-carbon heating is installed in all homes by 2050. In our pathway, this is all electric with no role for hydrogen in home heating. Heat pumps will play a key role, primarily as standalone systems, but also within communal systems, and it is essential that their deployment accelerates rapidly.
  - In our pathway, the share of existing homes with low-carbon heating reaches 23% by 2033, compared to 9% in 2023.[33] The vast majority of heating systems that are changed compared to the baseline (95%) are replaced with either an individual or communal heat pump, corresponding to 16% of all existing homes by 2033 (Figure 3.4g).
  - Annual heat pump installations in existing homes in Wales increase rapidly from 2025, reaching nearly 25,000 in 2030 and over 80,000 by 2035. In our pathway, installation rates do not exceed natural replacement cycles – the replacement of a heating system at the end of its life.
  - Wales, and the UK in general, is significantly behind on heat pump installations compared to other European countries. Our assumed compound annual growth rate for heat pump deployment is based on the rate of scale-up observed across a range of other European countries with comparable markets, including the Netherlands and Ireland.
- **Energy efficiency (19% of emissions reduction in 2033).** Energy efficiency measures include draught-proofing, loft insulation, floor insulation, and insulation for cavity and solid walls. These measures reduce heating energy demand by reducing the rate of heat loss.
  - Energy efficiency improvements are deployed ahead of low-carbon heating, and therefore account for a larger proportion of emissions reduction in the early years of the pathway.
  - By 2033, 18% of homes in Wales have received big energy efficiency measures (nearly 280,000 measures). Around 1.2 million small energy efficiency measures are installed in homes in Wales by 2033.*
- **New homes, lighting, electrical appliances, other household appliances, and energy-saving practices (39% of emissions reduction in 2033).**

* 'Big' energy efficiency measures include loft insulation, wall insulation, and floor insulation. 'Small' energy efficiency measures include a variety of low-cost measures, including draught-proofing and hot water tank insulation.

- Our pathway assumes that all new homes are highly efficient and have low-carbon heating systems.

- Our pathway assumes that all domestic energy-using products are decarbonised and/or replaced with more efficient equivalents by 2050.

- Our pathway assumes that some of the recent emissions reduction was due to behaviours that will be maintained into the future, such as reducing boiler flow temperatures, adjusting thermostats, and other steps to reduce energy bills.

Key actions to deliver the Balanced Pathway in residential buildings

Policy in the residential buildings sector is partly devolved, including planning and building regulations, energy efficiency schemes, and policy to address fuel poverty. Wales is included within the UK Government's Boiler Upgrade Scheme, which provides incentives to switch to low-carbon heating. The key recommended actions for the Welsh Government are as follows:

- Put in place requirements on housing developers ensuring no new properties completed from 2026 use fossil fuel heating systems. Deliver changes to Building Regulations with stringent transition arrangements which ensure that, from 2026, all new homes are built with low-carbon heating systems.

- Introduce regulations to ensure that, beyond 2035, all heating systems installed are low carbon.

- Support improvements to home energy efficiency, particularly in social housing, and provide targeted support to ensure that poorly insulated homes are not a barrier to uptake of low-carbon heating systems for low-income households.

3.2.7 Waste

Emissions in waste

In 2022, waste was the seventh highest-emitting sector in Wales, accounting for 3% of Wales' emissions.

Emissions in waste have fallen by 67% from 3.6 $MtCO_2e$ in 1990 to 1.2 $MtCO_2e$ in 2022.

- The main cause of this fall is a decrease in waste arisings and reduction in waste to landfill, combined with a steep increase in the municipal recycling rate.[34]

- While this progress was partly driven by the introduction of the Landfill Tax, the Welsh Government has delivered a range of policies to improve recycling, such as making food waste collections mandatory and setting statutory recycling targets for Local Authorities.[35]

- However, since 2010, emissions have decreased at a slower rate, while recycling improvements have also slowed.

The Balanced Pathway for waste

In our pathway, waste emissions fall by 27% from 1.2 $MtCO_2e$ in 2022 to 0.9 $MtCO_2e$ by 2033.

The key measures that combine to reduce emissions in waste are:

- **Waste reduction from waste prevention (50% of emissions reduction in 2033).** Waste reduction is enabled by improving resource efficiency, reducing food waste, and increasing recycling rates.

  - Our UK Balanced Pathway assumes the combined recycling rate for household, commercial, and industrial waste, including non-household municipal waste, reaches 68% by 2035, an increase from 47% in 2025. Our pathway assumes a similar rate of improvement in combined recycling rates for Wales as we do for the UK overall.

  - Wales has outperformed the rest of the UK in improving municipal recycling, and so our pathway implies Wales going further than our recommended UK level by 2035. We think this is justified due to Wales' ambitious recycling targets and because a proportion of English waste which is understood to be disposed of in Wales is included when translating our UK-wide recycling rate to Wales.

    - Wales has a statutory target for local authorities to recycle 70% of waste, a rate already being achieved in five of the 22 local authorities in Wales.[36;37]

    - By 2030, Wales aims to have a 75% municipal and industrial recycling rate which, although not directly comparable, we expect to be compatible with our pathway.[*;38]

  - Our UK pathway assumes a 39% reduction in total food waste per capita by 2030 compared to 2021 levels, which is aligned to the Courtauld Commitment 2030 and the UN's Sustainable Development Goal (SDG) 12.3. Wales is a signatory to the Courtauld Commitment and also has a goal to reduce avoidable food waste by 60% versus 2007 levels.[39]

  - Our pathway assumes the near elimination of biodegradable waste to landfill by 2028 across the UK. We also assume an elimination of all waste sent to landfill in 2045. The Landfill Allowances Scheme in Wales has reduced the amount of biodegradable municipal waste sent to landfill by 91% between 2005 and 2019.[40]

- **CCS at EfW plants (31% of emissions reduction in 2033).** CCS is installed at current EfW plants.

  - Wales currently has two EfW plants.[41] In the pathway, the plant in North Wales installs CCS in 2028 by connecting to the HyNet industrial cluster. The plant near Cardiff is assumed to adopt CCS as part of the South Wales Industrial Cluster from 2033.

- **Landfill methane capture (13% of emissions reduction in 2033).** We assume methane capture rates at landfill sites increase to 60% by 2033, up from 49% in 2022.

- **Wastewater treatment improvements (5% of emissions reduction in 2033).** Nitrous oxide emissions for municipal and industrial wastewater treatment are addressed through covering and containment, membrane aerated biofilm reactors, and enhanced emissions monitoring. Methane emissions are addressed through advanced anaerobic digestion.

  - Covering and containment, enhanced monitoring and real-time control, and digital twins are rolled out from 2025. Membrane aerated biofilm reactors are rolled out from 2030.

[*] Our 68% target is a UK-wide target comprising municipal, commercial, and industrial waste. It is based on UK-level recycling data and cannot be directly compared to Welsh recycling rates, which are defined in a different way.

- Advanced anaerobic digestion is already in widespread use and is rolled out to all plants by 2030. Industrial wastewater improvements lag five years behind the municipal wastewater sector in our pathway.

Key actions to deliver the Balanced Pathway in waste

Policy in the waste sector is largely devolved, although the Welsh Government is part of efforts led by the UK Government to introduce UK-wide waste reforms including extended producer responsibility (EPR). The key recommended actions for the Welsh Government are as follows:

- Wales has a strong record on recycling and the Welsh Government should introduce policies to deliver their ambitious recycling and waste objectives.
- The Welsh Government should work with industry and local authorities to bring forward plans for installing CCS at Wales' existing EfW plants. New EfW capacity should only be developed where a viable route to connecting to CCS can be established.
- Ofwat and the Welsh Government should encourage improved monitoring of wastewater emissions, as well as investment in technology development and deployment to reduce emissions from wastewater.

3.2.8 Non-residential buildings

Emissions from non-residential buildings

In 2022, non-residential buildings was the eighth highest-emitting sector in Wales, accounting for 2% of Wales' emissions.

Emissions from non-residential buildings have fallen by 45% from 1.6 $MtCO_2e$ in 1990 to 0.9$MtCO_2e$ in 2022.

- This decrease has been driven by lower emissions in the public sector, with a small reduction in emissions from commercial buildings. Improvements in public sector energy intensity have contributed to this.[42]

The Balanced Pathway for non-residential buildings

In our pathway, non-residential building emissions fall by 57% from 0.9 $MtCO_2e$ in 2022 to 0.4 $MtCO_2e$ by 2033.

The key measures that combine to reduce emissions in non-residential buildings are:

- **Energy efficiency (52% of emissions reduction in 2033).** Deployment of a wide range of measures saves 30% of energy use in public buildings and 21% in commercial buildings.
- **Low-carbon heating (36% of emissions reduction in 2033).** Current heating systems are replaced by low-carbon alternatives. Most heating is delivered by efficient heat pumps, whether this be through a district heat network or individual systems.
- **Electrification of catering and other non-heat fossil fuel uses (11% of emissions reduction in 2033).** Other uses of fossil fuels are electrified.
- **Anaesthetics (2% of emissions reduction in 2033).** Our pathway includes a 40% reduction in nitrous oxide emissions from anaesthetics used in healthcare by 2032 compared to levels in 2019/20, through the use of waste reduction measures.

Key actions to deliver the Balanced Pathway in non-residential buildings

Policy in the non-residential buildings sector is partly devolved. The key recommended actions for the Welsh Government are as follows:

- Introduce a comprehensive multi-year programme for decarbonisation of public sector buildings. This should set out strategic plans for when best to take the required decarbonisation actions in buildings across the public estate and should be supported by long-term capital settlements.

- Develop and implement an engagement strategy to provide clear information to businesses about their role in decarbonising non-residential buildings.

3.2.9 Shipping

Emissions in shipping

In 2022, shipping was the ninth highest-emitting sector in Wales, accounting for 2% of Wales' emissions.* Emissions had started to rebound after the COVID-19 pandemic, but were 5% lower than in 2019.

Emissions from shipping have decreased by 45% from 1.1 $MtCO_2e$ in 1990 to 0.6 $MtCO_2e$ in 2022.

- International shipping emissions were 0.3 $MtCO_2e$ in 2022, 42% below 1990 emissions and 10% below 2019 emissions.

- Domestic shipping emissions were 0.3 $MtCO_2e$ in 2022, 45% below 1990 emissions and 1% above 2019 emissions.

- Naval shipping emissions were 0.02 $MtCO_2e$ in 2022, 74% below 1990 emissions and 7% below 2019 emissions.

The Balanced Pathway for shipping

In our pathway, shipping emissions fall by 41% between 2022 and 2033. International shipping emissions decrease by 40% and domestic shipping emissions decrease by 44%.

The key elements that combine to reduce emissions in shipping are:

- **Efficiency improvements (69% of emissions reduction in 2033).** This measure consists of a variety of technological and operational measures that improve the energy efficiency of a ship, such as wind assistance, propeller ducts, rudder bulbs, and speed optimisation.

- **Fuel switching (31% of emissions reduction in 2033).** Existing and new ships take up engines and other propulsion systems capable of running on low-carbon fuels and electricity. The rate at which ships switch to these fuels is determined by the pace at which the technologies and fuels become available and cost-effective, as well as the impact of assumed fuel standard regulations.

* We have used the UK Department for Transport's (DfT) emissions model as the starting point for our pathway (other than for naval shipping and inland waterways and leisure shipping, which are not included in DfT's emissions model and are based on the GHG inventory). The Balanced Pathway uses more recent activity data (from 2019) for most domestic shipping than is used for the inventory. We have used this approach as we expect the inventory to adopt a similar methodology for domestic shipping in the near future. As a result, our starting point for shipping emissions is slightly higher than in the inventory. The emissions reduction between 2022 and 2033 is calculated based on DfT's accounting approach.

- Low-carbon fuels and electricity make up 13% of total energy use in 2033. Our pathway includes a variety of fuels, all of which are likely to play a role in decarbonising shipping.

- The fuels used most in our pathway are low-carbon ammonia and synthetic fuels (produced by combining low-carbon hydrogen with CO_2 from direct air capture).

Key actions to deliver the Balanced Pathway in shipping

Policy in the shipping sector is largely reserved, except for ports and inland waterways. The key recommended actions for the Welsh Government are as follows:

- Work closely with the UK Government to support fuel switching to low-carbon fuels or electricity on vessels, and adoption of efficiency improving measures.

- Develop policies to reduce emissions at berth and ensure that the required port infrastructure is in place. Additionally, ensure there are infrastructure and incentives in place to reduce emissions on inland waterways.

3.2.10 F-gases

Emissions of F-gases

In 2022, F-gases was the 10th highest-emitting sector in Wales, accounting for 1% of Wales' emissions.

Emissions of F-gases have risen by 17% from slightly below 0.3 $MtCO_2e$ in 1995 to slightly above 0.3 $MtCO_2e$ in 2022.

- An increase in the use of air conditioning and refrigeration appliances saw emissions increase until the mid-2010s.[43]

- The F-gas Regulation (2015) then reduced F-gases emissions by phasing down the amount of hydrofluorocarbons (HFCs) that can be placed on the market.[44]

The Balanced Pathway for F-gases

In our pathway, F-gases emissions fall by 59% from 0.3 $MtCO_2e$ in 2022 to 0.1 $MtCO_2e$ by 2033.

The key measures that combine to reduce F-gas emissions are:

- **Refrigeration (36% of emissions reduction in 2033) and air conditioning and heat pumps (27% of emissions reduction in 2033).** This involves taking care to remove F-gases in refrigeration, air conditioning, and heat pumps when that equipment has reached the end of its life, as well as the use of lower-global-warming-potential (GWP) refrigerants in refrigeration, air conditioning, and heat pumps.

- **Inhalers (37% of emissions reduction in 2033).** This involves replacing use of high-GWP propellants in inhalers with lower-GWP propellants. This can involve using dry powder inhalers (for patients who can switch to this device) or using metered-dose inhalers with alternative propellants (for patients who cannot switch to dry powder inhalers).

Key actions to deliver the Balanced Pathway in F-gases

Delivering the pathway in F-gases will depend on a clear regulatory framework that stimulates the necessary innovation and deployment for decarbonisation. This is largely reserved, although we expect decisions around inhalers to fall under devolved health policy.

3.2.11 Aviation

Emissions in aviation

In 2022, aviation was the 11th highest-emitting sector in Wales, accounting for around 0.3% of Wales' emissions.

In addition to flights from Cardiff airport that are included here, Welsh passengers take flights from English airports, such as Bristol, Manchester, and Birmingham. These emissions are accounted for in UK-wide aviation emissions.[*]

Emissions in aviation have halved from 0.2 $MtCO_2e$ in 1990 to 0.1 $MtCO_2e$ in 2022. However, 2022 emissions have not yet rebounded to pre-COVID-19 pandemic levels, which is reflected in the figures below:

- The main factors affecting aviation emission trends are the overall demand for flights and the extent to which efficiency improvements, such as plane loadings, have offset increased demand.[†]
  - International aviation emissions were 0.07 $MtCO_2e$ in 2022, 8% below 1990 emissions and 44% below 2019 emissions.
  - Domestic aviation emissions were 0.003 $MtCO_2e$ in 2022, 69% below 1990 emissions and 70% below 2019 emissions.
  - Military aviation emissions were 0.04 $MtCO_2e$ in 2022, 77% below 1990 levels.

The Balanced Pathway for aviation

As in our UK-wide advice, the aviation sector takes responsibility for reducing its emissions to Net Zero by 2050 through paying to deploy sustainable aviation fuels (SAF), engineered removals, efficiency improvements, and low-emissions aircraft. The overall increase in costs results in a reduction in demand relative to the baseline projection. In our pathway, following a further rebound from COVID-19, aviation emissions in Wales slightly decrease by 3% between 2025 and 2033.

The key measures that combine to address aviation emissions are:

- **Demand (58% of emissions reduction in 2033).** Our analysis assumes that industry adopting the cost of aviation decarbonisation will help to manage demand relative to the growth seen in the baseline projection.

[*] A Civil Aviation Authority passenger survey report from 2019 collected data on passenger origin, which shows that 4.5 million passengers travelled from Wales to English airports. For reference, in 2019 Cardiff Airport processed 1.6 million terminal passengers.

[†] Currently there is no data on aviation turbine fuel supply to Wales, therefore the fuel efficiency of the Welsh aviation sector cannot be calculated.

  - The Government's high carbon values are included in the cost of flying to forecast future demand to account for uncertainties in technology development, likely high SAF and engineered removals costs, and non-CO_2 effects.[45]

  - Aviation demand can only grow if aviation sector technology rollout progresses and begins to abate and offset aviation emissions, with demand management playing an important role in reducing emissions in the 2020s and 2030s while the availability of SAF and engineered removals to offset fossil fuel use is limited.

- **SAF (35% of emissions reduction in 2033).** In line with the CCC's UK-wide SAF pathway, SAF meets 10% of fuel demand for Welsh flights by 2033, compared to less than 1% at a UK-wide level in 2023 (Figure 3.4h).

- **Efficiency improvements and hybrid- and zero-emission aircraft (7% of emissions reduction in 2033).** Fuel, operational, and air transport movement efficiencies improve to reduce the carbon intensity of flying by 1.3% per year on average between 2025 and 2050. Hybrid electric aircraft uptake is assumed in time for the Fourth Carbon Budget period, while battery-electric aircraft enter the fleet only after the budget period.

- **Permanent engineered removals**. Engineered removals are used to balance long-lived CO_2 emissions from fossil fuels. By 2050, all residual aviation emissions are offset by engineered removals. For more information on removals technologies, see Section 3.2.12.

Key actions to deliver the Balanced Pathway in aviation

Policy in the aviation sector is largely reserved, except for planning and consenting regulations related to airports. Cardiff Airport is the only civilian airport in Wales, and is owned by the Welsh Government as an arms-length company supported to benefit economic development and tourism. The key recommended actions for the Welsh Government are as follows:

- Work with the UK Government to develop and implement policy - such as the existing SAF mandate and the UK Emissions Trading Scheme (ETS) - that ensures the aviation sector takes responsibility for mitigating its emissions and ultimately achieving Net Zero for flying.

- Support the rollout of domestically produced SAF through projects such as Project Dragon in Port Talbot.[46]

- Support innovation and commercialisation of low- and zero-emission aircraft. Routes connecting Cardiff to, for example, Scotland and the island of Ireland might provide opportunities for decarbonising shorter-distance journeys.

3.2.12 Engineered removals

Emissions in engineered removals

Engineered removals are measures that remove CO_2 from the atmosphere to permanent storage. Other than small-scale testing, there have been no engineered removals recorded to date in Wales.

Globally, some engineered removals are taking place, mostly in the bioenergy with carbon capture and storage (BECCS) and biochar sectors, and there is a growing pipeline of projects under development.[47]

The Balanced Pathway for engineered removals

In our pathway, engineered removals start contributing in 2028. They reach -0.3 $MtCO_2e$ by 2033 and -1.8 $MtCO_2e$ by 2050 (Figure 3.4i). The amount in 2050 is driven by the need for the UK as a whole to balance residual emissions to achieve Net Zero, with Wales' share of engineered removals technologies based on individual assumptions described below.

Engineered removals are achieved through three groups of technologies:

- **Direct air carbon capture and storage (DACCS) (56% of engineered removals in 2050).** DACCS is a group of technologies designed to extract CO_2 directly from the atmosphere through chemical and physical methods and send it to permanent geological storage. DACCS starts contributing in 2035. Across the nations of the UK, DACCS is shared equally between planned CCS clusters; Wales is assumed to account for half of the HyNet cluster.

- **BECCS (38% of engineered removals in 2050).** BECCS is the burning or converting of a biomass resource in a process with CCS applied. By capturing biogenic CO_2 and sending it to permanent geological storage, BECCS is a net negative emissions process. In our pathway, it starts contributing in 2028, and features in industry (specifically cement and chemicals), waste, and fuel production. Wales' share of UK-wide BECCS processes is based on a combination of alignment with existing facilities, and the fuel demands of the Welsh population.

- **Enhanced weathering and biochar (6% of engineered removals in 2050).** These are removals approaches that rely on land- and water-based CO_2 storage. Enhanced weathering involves speeding up the natural process of rock weathering through grinding and spreading rock on land to accelerate its reaction with CO_2 in the atmosphere to form bicarbonates. These bicarbonates are gradually washed via rivers into the sea where the carbon is stored for centuries or more. Biochar as a removal involves heating biogenic wastes in the absence of oxygen to form a stable carbon-rich biochar, which is resistant to breaking down and can be spread onto and absorbed by soils.

  - In our pathway, enhanced weathering and biochar make only a small contribution, starting in 2030. Recent developments indicate they have significant potential, but more work is needed to confirm and quantify this.[48]

  - Across the nations of the UK, enhanced weathering and biochar are distributed according to the share of temporary grassland, cropland, and rough grazing land, these being the land types where active trials are underway.

Who pays for engineered removals is a policy choice. In our UK Seventh Carbon Budget advice, we largely assume that engineered removals are funded in line with a 'polluter pays' principle, in which case these costs would fall UK-wide rather than necessarily to people in Wales.

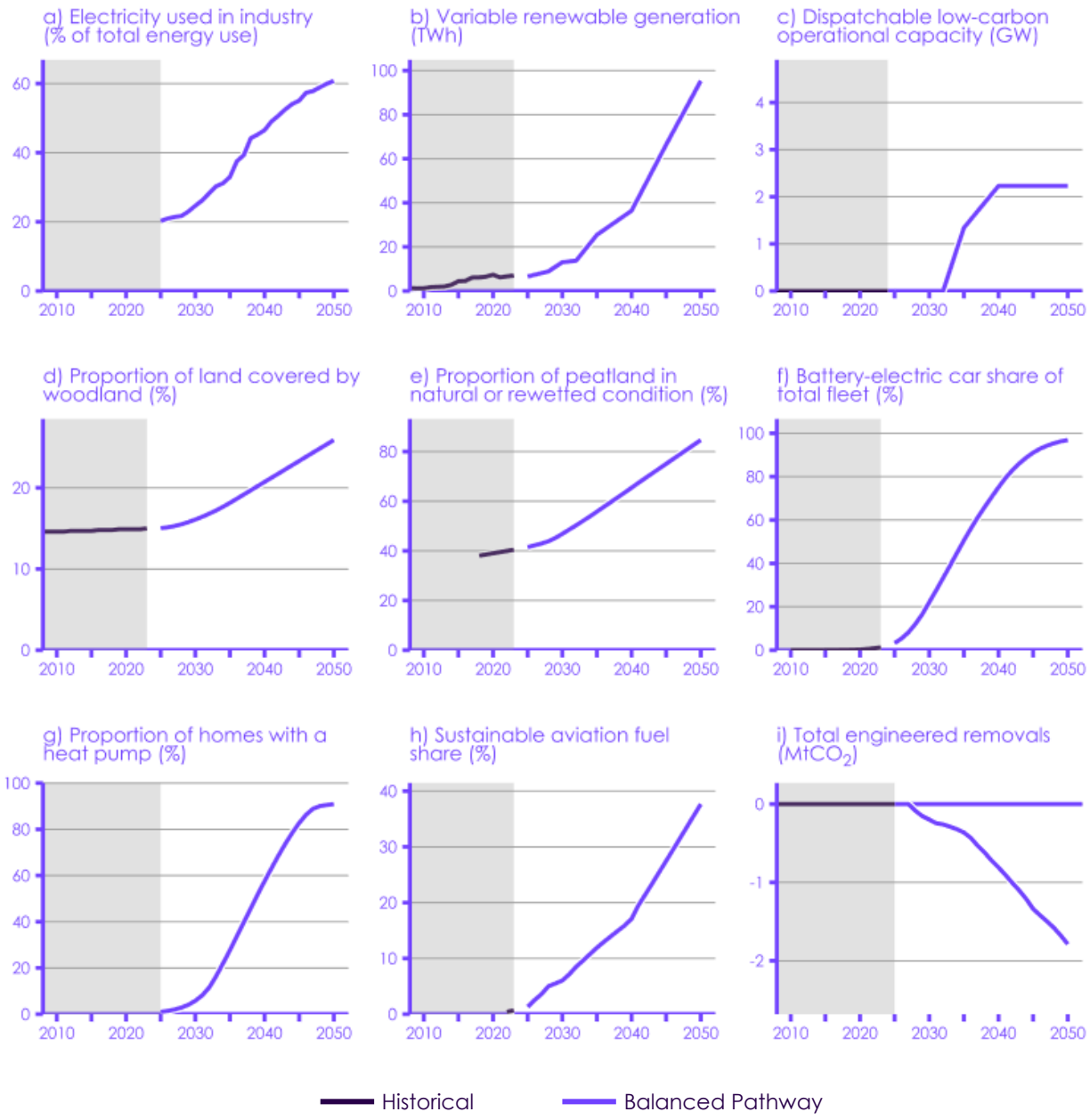
Key actions to deliver the Balanced Pathway in engineered removals

Policy to deliver large-scale industrial engineered removals, such as developing the associated business models, is largely reserved. The key recommended actions for the Welsh Government are as follows:

- Work with the UK Government to develop the CO_2 transport and storage infrastructure necessary to deploy CCS-based removals at scale.

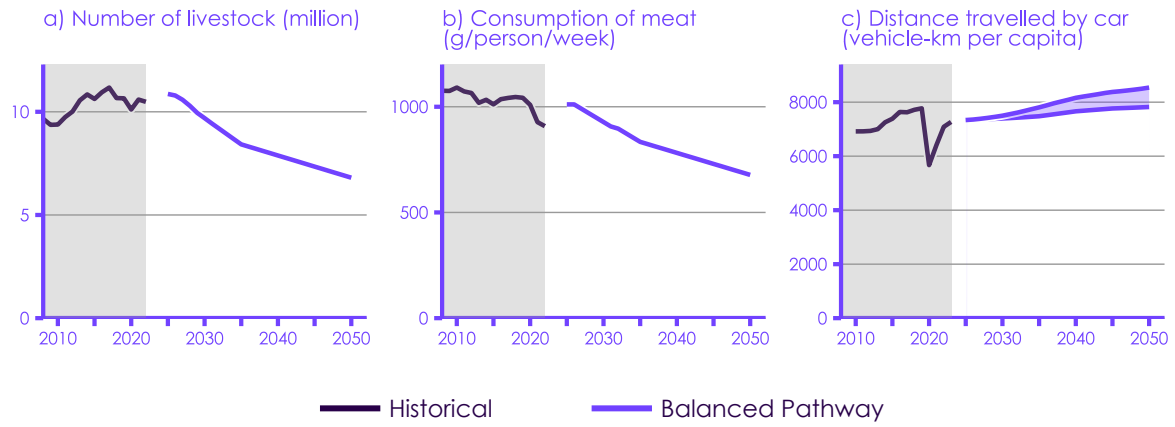
- Consider implementing policy to improve understanding and increase delivery of enhanced weathering and biochar at scale in the Welsh context. Growing these approaches would create optionality between engineered removals technologies, giving, for example, the possibility to substitute for some of the DACCS in the Balanced Pathway.

Figure 3.4 Key indicators of roll-out of low-carbon technologies and land-based actions in the Balanced Pathway



Description: The key quantity indicators of the roll-out of low-carbon technologies and land-based actions in our pathway show continued growth in renewables, growth that follows an S-curve in the electrification of cars, home heating, and industry, a ramp-up in tree planting and peatland restoration rates, and growing contributions from low-carbon fuels and engineered removals.
Source: Historical data from UK DESNZ, UK DfT, National Atmospheric Emissions Inventory (NAEI), Forest Research, UK Centre for Ecology & Hydrology, and UK Department for Environment, Food and Rural Affairs (Defra); CCC analysis.
Notes: (b) Projected generation is based on an average weather year. (d) Historical woodland area is based on the September 2024 Woodland Statistics release. Our modelling is underpinned by the 2021 National Forest Inventory (NFI) estimates of woodland area. (g) The chart shows the share of existing homes that are heated by a heat pump in each year, including homes with individual heat pumps and those connected to communal heat pump systems. This share does not include homes connected to low-carbon heat networks (some of which will use heat pumps). (h) The historical data shown here is for the UK as a whole as this data does not exist for Wales.

Figure 3.5 Key indicators of demand for high-carbon activities in the Balanced Pathway



Description: The key indicators of demand for high-carbon activities in our pathway show falling livestock numbers and the distance travelled by car growing more slowly than historical trends.
Source: Historical data from UK DfT, UK Defra, Office for National Statistics (ONS), and the Welsh Government; CCC analysis.
Notes: (a) Livestock numbers at the start of the pathway are higher than the most recent historical year due to a projected increase in sheep numbers in the baseline from 2022. (b) The historical data for meat consumption is for the UK as a whole rather than Wales. (c) The range represents the uncertain impact of rebound effects, which could increase driving as a result of the cheaper cost of driving offered by electric vehicles.

3.3 Contingency actions and options to go further

There are a range of uncertainties that could affect Wales' pathway to Net Zero (for example, those in the electricity supply sector, a sector with policy powers mostly reserved to the UK Government, see Box 3.1). In addition, there is a risk that policies could fail to deliver the expected levels of emissions reduction. In either case, it is important to monitor both the emissions trajectory and the underlying indicators of progress (see Section 3.2), as well as factors such as GDP, population, the GHG inventory, and costs, to enable early identification of a long-term risk of underperforming on emissions reduction.

Contingency options are action plans that can be implemented to deliver additional emissions reductions to make up for shortfalls in the pathway. As part of our advice on the UK's Seventh Carbon Budget (see Chapter 6 in our UK Seventh Carbon Budget advice report), we modelled a range of additional actions that could be used as contingencies or to go further than our pathway. As the time period covered by Wales' Fourth Carbon Budget is closer at hand than the UK's Seventh Carbon Budget period, the contingency actions that could have the largest impact are expected to be slightly different, with a larger potential role for actions to accelerate the decarbonisation of electricity supply and increase modal shift to public transport and active travel alongside measures to deliver faster take-up of EVs and heat pumps.

- Around two-thirds of cars on Welsh roads during the Fourth Carbon Budget period will still be powered by petrol and diesel. Therefore, measures to incentivise people to choose public transport or active travel over private car travel beyond what is assumed in our pathway could provide an important contingency option for this time period.

  - In our pathway, 6% of car-kilometres are shifted to alternative modes of travel by the middle of the Fourth Carbon Budget period. The Welsh Government has a more ambitious target than this - aiming to reduce per capita car-kilometres by 10% from 2019 levels by 2030. If policies are successful in delivering this, then this could provide significant contingency on top of our modelled pathway.

  - Investment in bus services and measures to restrict traffic can be implemented relatively quickly. The Welsh Government has already embedded its demand reduction target as part of wider policies, such as its roads review.

- During the Fourth Carbon Budget period, the vast majority of new cars sold will be EVs, with this share increasing to 100% by the end of the period. Incentives and effective public information campaigns could help grow demand sooner, allowing more EVs to enter the fleet more quickly.

  - In addition, scrappage schemes that incentivise owners of older, less efficient fossil fuel cars to replace these before end-of-life could begin to play a role during the Fourth Carbon Budget period, once EV markets have scaled up to become the dominant choice.

  - Early scrappage of vehicles is not included in the Balanced Pathway but could provide an option to go faster or to catch up if emissions reductions fall off track. As cars and vans are on average four and 18 months older than the UK average, scrappage of vehicles based on age could occur at a faster rate in Wales.[49]

- The heat pump market will be growing at pace by the time of the Fourth Carbon Budget, with a mix of consumer demand, supply chains, and growing installer bases expected to be constraining the rate at which this can occur. Earlier action to enable this market to scale up sooner could potentially deliver faster emissions reductions in Wales than in our pathway. Investment to deliver early take-up in buildings owned and managed by the public sector could help support these supply chains to grow quickly.

- In our Balanced Pathway, emissions in the electricity supply sector fall quickly over the 2020s but are still falling during the Fourth Carbon Budget period as the UK completes its transition to a fully low-carbon power system. Therefore, accelerated action to deliver aspects of this sooner could further reduce emissions during the Fourth Carbon Budget period. Many of these actions are reserved to the UK Government.

Box 3.1
Uncertainty in electricity supply emissions in Wales

The emissions profile in Wales is affected by a small number of large point sources, including those in the largely reserved electricity supply sector. Meeting the Third and Fourth Carbon Budgets in Wales relies on a rapid reduction in electricity supply emissions (see Figure 3.1).

The recommended levels of the first three carbon budgets allow for continued generation, though declining, from the large gas-fired power stations in Wales. Our recommended Fourth Carbon Budget target is based on hourly plant-level modelling of the electricity supply sector, conducted as part of modelling for the UK's Seventh Carbon Budget advice.

Electricity supply emissions in Wales will be strongly influenced by a range of factors including UK and international energy policy, demand for electricity in the UK and Wales, and company-specific decisions around dates of decommissioning or low-carbon conversion of unabated gas plants, as well as developments and operations in the wider system in Great Britain. Our analysis suggests the uncertainty around dates for unabated gas plant decommissioning or conversion could be around ±2 $MtCO_2e$ over the Fourth Carbon Budget period. Over the Fourth Carbon Budget period, total emissions are 75 $MtCO_2e$, of which around 5 $MtCO_2e$ are from electricity supply.

Emissions are also influenced by the weather, as unabated gas plant may need to run more in low-wind years and less in windier years. We base our emissions for the Balanced Pathway on the weather corresponding to an average emissions year. This reduces the risk of a single adverse year affecting the delivery of a carbon budget.

3.4 Traded emissions

Table 3.1 shows which sectors are partly covered by the UK Emissions Trading Scheme (ETS).

Table 3.1
Sectoral coverage of UK ETS

Sector	Covered by the UK ETS?
Agriculture	Not covered
Aviation	Partly covered
Electricity supply	Partly covered
Engineered removals	Not covered
F-gases	Not covered
Fuel supply	Partly covered
Industry	Partly covered
Land use	Not covered
Non-residential buildings	Not covered
Residential buildings	Not covered
Shipping	Partly covered from 2026
Surface transport	Not covered
Waste	Partly covered from 2028

Endnotes

[1] National Atmospheric Emissions Inventory (2024) *Devolved Administration GHG Inventory 1990-2022*. https://naei.energysecurity.gov.uk/reports/greenhouse-gas-inventories-england-scotland-wales-northern-ireland-1990-2022.

[2] UK Government (2024) *UK ETS public reports: UK ETS recorded emissions and surrendered allowances data 2024*. https://reports.view-emissions-trading-registry.service.gov.uk/ets-reports.html.

[3] National Atmospheric Emissions Inventory (2024) *Devolved Administration GHG Inventory 1990-2022*. https://naei.energysecurity.gov.uk/reports/greenhouse-gas-inventories-england-scotland-wales-northern-ireland-1990-2022.

[4] Department for Energy Security and Net Zero (2024) *Enabling Industrial Electrification. Call for evidence on fuel-switching to electricity: Summary of responses*. https://assets.publishing.service.gov.uk/media/66e013650f4ba0621b086702/electrification-call-for-evidence-formal-summary-of-responses.pdf.

[5] National Grid (2003) *Generation disconnections since 1991*. https://web.archive.org/web/20030508220159/http://www.nationalgrid.com/uk/library/documents/sys_03/ddownloaddisplay.asp?sp=sys_Table3_7.

[6] Department for Energy Security and Net Zero (2024) *Digest of UK Energy Statistics (DUKES): Electricity – Power stations in the United Kingdom, May 2023 (DUKES 5.11)*. https://www.gov.uk/government/statistics/electricity-chapter-5-digest-of-united-kingdom-energy-statistics-dukes.

[7] RWE (2025*) Aberthaw power plant*. https://uk.rwe.com/locations/aberthaw-power-plant/.

[8] Department for Environment, Food & Rural Affairs and the Scottish Government (2024) *The British Survey of Fertiliser Practice, 2023*. Microsoft Word - BSFP_2023_15.07.24 CJD TO PRINT.doc.

[9] House of Lords Library (2022) *Rising cost of agricultural fertiliser and feed: Causes, impacts and government policy*. https://lordslibrary.parliament.uk/rising-cost-of-agricultural-fertiliser-and-feed-causes-impacts-and-government-policy/#heading-2.

[10] Department for Environment, Food & Rural Affairs (2024) *Family food survey*. https://www.gov.uk/government/statistics/family-food-fye-2023.

[11] Pastorino et al. (2023) *The future of meat and dairy consumption in the UK: exploring different policy scenarios to meet net zero targets and improve population health*. https://www.cambridge.org/core/journals/global-sustainability/article/future-of-meat-and-dairy-consumption-in-the-uk-exploring-different-policy-scenarios-to-meet-net-zero-targets-and-improve-population-health/8F4D09F2A88EF2FA16E2E237B5F30B21.

[12] Meat Promotion Wales (2025) *Industry Statistics*. https://meatpromotion.wales/en/market-intelligence/industry-statistics/.

[13] Welsh Government (2021) *Net Zero Wales Carbon Budget 2 (2021 – 25)*. https://www.gov.wales/sites/default/files/publications/2021-10/net-zero-wales-carbon-budget-2-2021-25.pdf.

[14] Department for Transport (2024) *VEH1103: Vehicle licensing statistics data tables*. https://www.gov.uk/government/statistical-data-sets/vehicle-licensing-statistics-data-tables.

[15] Department for Transport (2024) *VEH1153: Vehicle licensing statistics data tables*. https://www.gov.uk/government/statistical-data-sets/vehicle-licensing-statistics-data-tables.

[16] Department for Transport (2024) *VEH1103: Vehicle licensing statistics data tables*. https://www.gov.uk/government/statistical-data-sets/vehicle-licensing-statistics-data-tables.

[17] Department for Transport (2024) *Electric vehicle public charging infrastructure statistics: July 2024*. https://www.gov.uk/government/statistics/electric-vehicle-public-charging-infrastructure-statistics-july-2024/electric-vehicle-public-charging-infrastructure-statistics-july-2024.

[18] Department for Transport (2024) *VEH1153: Vehicle licensing statistics data tables*. https://www.gov.uk/government/statistical-data-sets/vehicle-licensing-statistics-data-tables.

[19] Department for Transport (2024) *VEH1153: Vehicle licensing statistics data tables*. https://www.gov.uk/government/statistical-data-sets/vehicle-licensing-statistics-data-tables.

[20] Department for Transport (2024) *VEH1107: Vehicle licensing statistics data tables*. https://www.gov.uk/government/statistical-data-sets/vehicle-licensing-statistics-data-tables#all-vehicles.

[21] Department for Transport (2024) *Electric vehicle public charging infrastructure statistics: July 2024*. https://www.gov.uk/government/statistics/electric-vehicle-public-charging-infrastructure-statistics-july-2024/electric-vehicle-public-charging-infrastructure-statistics-july-2024.

[22] Welsh Government (2021) *Electric vehicle charging strategy for Wales*. https://www.gov.wales/sites/default/files/publications/2021-03/electric-vehicle-charging-strategy-wales.pdf.

[23] Mobilität in Deutschland (2017) *Mobilität in Tabellen*. https://mobilitaet-in-tabellen.dlr.de/login.html?brd.

[24] CBS StatLine (2024) *Mobility; per person, modes of travel, purposes of travel and regions*. https://opendata.cbs.nl/statline/#/CBS/en/dataset/84710ENG/table?ts=1695198666028.

[25] Welsh Government (2024) *Active travel delivery plan 2024 to 2027*. https://www.gov.wales/sites/default/files/publications/2024-03/active-travel-delivery-plan-2024-to-2027.pdf.

[26] Welsh Government (2023) *National transport delivery plan 2022 to 2027*. https://www.gov.wales/sites/default/files/publications/2023-02/national-transport-delivery-plan-2022to2027.pdf.

[27] Transport for Wales (2024) *First electric trains to be introduced to South Wales Metro*. https://news.tfw.wales/news/first-electric-trains-to-be-introduced-to-south-wales-metro.

[28] Beaufort Research (2023) *Climate Action Wales Behavioural Tracking Survey 2023*. https://www.gov.wales/sites/default/files/publications/2024-09/climate-action-wales-behavioural-tracking-survey-2023.pdf.

[29] Department for Energy Security and Net Zero (2023) *UK Greenhouse Gas Inventory, 1990 to 2021, Section 1.8.2.3*. UK Greenhouse Gas Inventory, 1990 to 2021.

[30] Office for National Statistics (2024) *Main fuel type or method of heating used in central heating, England and Wales*. https://www.ons.gov.uk/peoplepopulationandcommunity/housing/datasets/mainfueltypeormethodofheatingusedincentralheatingenglandandwales.

[31] Department for Energy Security and Net Zero (2024) *Household Energy Efficiency Statistics*. https://www.gov.uk/government/collections/household-energy-efficiency-national-statistics.

[32] Welsh Government (no date) *Building regulations: boilers and heating*. https://www.gov.wales/building-regulations-boilers-and-heating#:~:text=Each%20boiler%20must%20have%20a,why%20one%20cannot%20be%20installed.

[33] Office for National Statistics (2024) *Main fuel type or method of heating used in central heating, England and Wales*. https://www.ons.gov.uk/peoplepopulationandcommunity/housing/datasets/mainfueltypeormethodofheatingusedincentralheatingenglandandwales.

[34] Welsh Government (2023) *Local Authority Municipal Waste Management, 2021-22 (Revised)*. https://www.gov.wales/sites/default/files/statistics-and-research/2023-01/local-authority-municipal-waste-management-april-2021-march-2022-revised.pdf.

[35] Welsh Government (2020) *Press Release: How Wales became a world leader in recycling*. https://www.gov.wales/how-wales-became-world-leader-recycling#:~:text=Wales%20has%20robust%20collection%20regimes,7. (Accessed: February 2025).

[36] Department for Environment, Food & Rural Affairs (2024) *UK statistics on waste*. https://www.gov.uk/government/statistics/uk-waste-data/uk-statistics-on-waste.

[37] Welsh Government (2023) *New waste and recycling stats published today*. https://www.gov.wales/new-waste-and-recycling-stats-published-today.

[38] Welsh Government (2021) *Beyond Recycling*. https://www.gov.wales/sites/default/files/publications/2021-03/beyond-recycling-strategy-document.pdf.

[39] Welsh Government (2021) *Beyond Recycling*. https://www.gov.wales/sites/default/files/publications/2021-03/beyond-recycling-strategy-document.pdf.

[40] Natural Resources Wales (2021) *Landfill Allowance Scheme*. https://naturalresourceswales.gov.uk/evidence-and-data/research-and-reports/waste-reports/landfill-allowance-scheme/?lang=en#:~:text=Summary%20of%202019%2F20%20results,cent%20less%20than%20the%20allowance.

[41] Welsh Government (2021) *Energy Generation in Wales*. https://www.gov.wales/sites/default/files/publications/2023-11/energy-generation-in-wales-2022.pdf.

[42] Committee on Climate Change (2016) *Meeting Carbon Budgets – Progress Report to Parliament*. https://www.theccc.org.uk/publication/meeting-carbon-budgets-2016-progress-report-to-parliament/.

[43] European Union (2022) *About F-gases*. https://climate.ec.europa.eu/eu-action/fluorinated-greenhouse-gases/about-f-gases_en.

[44] European Union (2015) *The Fluorinated Greenhouse Gases Regulations 2015*. https://www.legislation.gov.uk/uksi/2015/310/contents.

[45] Department for Energy Security and Net Zero (2023) *Traded carbon values used for modelling purposes*. https://www.gov.uk/government/publications/traded-carbon-values-used-for-modelling-purposes-2023.

[46] UK Government (2024) *Advanced Fuel Fund (AFF) competition winners*. https://www.gov.uk/government/publications/advanced-fuels-fund-competition-winners/advanced-fuels-fund-aff-competition-winners.

[47] Smith, S. et al (2024) *The state of carbon dioxide removal 2024 - 2nd Edition*. doi:10.17605/OSF.IO/F85QJ. https://www.researchgate.net/publication/383025929_The_State_of_Carbon_Dioxide_Removal_2024_-_2nd_Edition.

[48] UK Government (2021) *Greenhouse gas removal methods: technology assessment report*. https://www.gov.uk/government/publications/greenhouse-gas-removal-methods-technology-assessment-report.

[49] Department for Transport (2024) *VEH1107: Vehicle licensing statistics data table*. https://www.gov.uk/government/statistical-data-sets/vehicle-licensing-statistics-data-tables#all-vehicles.

Chapter 4: Households, nature, and the economy

Introduction and key messages

This chapter describes the role of households in our pathway; how households, the economy, businesses, and workers may be affected; the well-being of future generations; and the state of natural resources.

Our key messages are:

- The key changes households can make will be to buy heat pumps and electric cars when it is time to replace fossil fuel boilers or cars, to eat less meat and dairy, to keep flying close to today's levels until technology develops, and to switch some car journeys to public transport or active travel. Policy and business action will need to make household low-carbon choices easy, attractive, and affordable, and ensure trusted information is provided.

- The transition can help support the goals of the Well-being of Future Generations Act, provided appropriate policy is in place. Households in Wales, including those in less energy efficient houses or in fuel poverty, will benefit from more efficient technologies, lower bills, less draughty homes, and cleaner air. This helps promote a healthier Wales and, with suitable policy in place, can support a more equal Wales.

- The transition will make the economy more resilient, from reduced reliance on international fossil fuel markets. Most sectors of the economy will see little change in activity other than switching to low-carbon heating and vehicles.

- Production of livestock agriculture will reduce, with knock-on impacts for farmers and communities. The Welsh Government needs to engage with farmers and their communities, and support them to diversify their incomes, including towards woodland creation and peatland restoration, keeping in mind implications for Welsh heritage and culture.

- Energy-intensive manufacturing, a relatively important part of the Welsh economy, will face additional costs to eliminate emissions. The UK and Welsh Governments should ensure the right incentives are in place for these sectors to switch to low-carbon production, and work closely with workers, unions, communities, and businesses to put in place funded transition plans that ensure attractive employment opportunities.

- Transitioning to a low-carbon economy can safeguard and enhance Wales' natural resources, promote the Welsh regenerative economy, and provide a stepping stone for improving ecosystem resilience.

4.1 Households

The transition from now until 2050 will involve changes that directly involve households. The most significant changes involving household choices cover four areas: cleaner and more efficient home heating, cleaner and more efficient road travel, keeping flying close to today's levels until technology develops, and a reduction in average meat and dairy consumption.

- **Electric cars and modal shift:** the transition involves households replacing petrol and diesel cars with cleaner and more efficient electric cars, when a car is being replaced anyway. By 2033 in our pathway, 39% of cars on the road are electric. Our pathway includes households replacing some private car journeys with other modes of transport. Modal shift for Wales involves 6% of baseline car demand switching to public transport, cycling, and walking by 2033, with the reduction in car-kilometres primarily achieved in more built-up urban areas.*

- **Low-carbon heating system and energy efficiency measures:** the transition involves households replacing fossil fuel boilers for home heating with cleaner and more efficient heat pumps, when they are ready to be replaced.† This includes the four-fifths of households in Wales who use gas as their main heating system and the 7% of households who rely on oil.[1] Many households will install energy efficiency measures such as cavity wall, loft, and floor insulation . As discussed below, the benefits of more efficient heating, lower running costs, and less draughty homes may particularly be felt by households in Wales in less energy efficient houses or in fuel poverty.

- **Reduction in average meat and dairy consumption:** by Wales' Fourth Carbon Budget period, emissions from agriculture are a significant proportion of remaining emissions, with limited options to deliver reductions. Households consuming on average less meat and dairy reduces emissions directly from livestock and frees up land to enable peatland restoration and tree planting. It also helps avoid a scenario in which the reduction in livestock in Wales results in an increase in imported meat and dairy (reducing the net impact on global emissions). The majority of beef and lamb produced in Wales is exported to the rest of the UK.[2]

- **Keeping flying close to today's levels until technology develops:** this reduces emissions compared to the baseline, with further impacts on reducing non-CO_2 effects.

- **Other actions:** this includes other household actions which play a smaller role in reducing emissions, such as energy-saving practices in homes; reducing waste and recycling more; switching to more energy efficient electrical appliances (for example, more efficient fridges); and switching to electric cooking appliances.

We convened a citizens' panel to explore the question of what an accessible and affordable vision of Net Zero would be for households, given the household low-carbon choices set out above and the associated costs and cost savings. The findings are presented in our UK Seventh Carbon Budget advice report.

With appropriate policy in place, households will benefit from lower running costs of electric cars and low-carbon heating. They will require support with the upfront costs of low-carbon heating, and policies to make choices easy, attractive, and affordable.

- In our advice on the UK Seventh Carbon Budget, we set out the findings of our distributional model. The model assesses the costs and savings experienced by 15 household archetypes, as a result of two illustrative policy packages that we assume will enable households to make the necessary changes to home energy use and car use. Our policy packages include support for upfront costs for home heating and action to reduce electricity prices.

* While overall car-kilometres continue to grow, modal shift reduces the growth rate compared to the baseline.

† In our analysis, the majority of households (over 90%) switch to a heat pump. A small number of households, particularly homes where heat pumps may not be an appropriate solution, will install other measures such as less efficient direct electric heating or district heating using a low-carbon heating source.

- The archetypes are selected to reflect characteristics of households across the whole of the UK, including income, how they travel, and how they heat their homes. As such, the spread of archetype characteristics will not directly reflect the spread of household characteristics in Wales. For example, Wales has a relatively high proportion of households living in a settlement of fewer than 5,000 people (around a quarter) compared to England.[3]

- Generally, we find that under the two illustrative policy packages, most household archetypes save over the transition period (from 2025 to 2050) when considering driving and home energy use, compared to a baseline of no further decarbonisation action. Savings from lower running costs of electric cars and low-carbon heating and home heating grants outweigh the additional upfront cost of low-carbon heating.

- In Wales, there is a relatively high rate of car ownership and car-kilometres driven per capita compared to the rest of the UK and compared to England.[4;5] Generally, our modelling finds that households that drive experience savings overall across the period 2025 to 2050 in transport, largely driven by the lower running costs of driving an electric car.

The transition will bring wider benefits to households in Wales, helping reduce fuel poverty and improve health from cleaner air and less draughty homes.

- In 2021, fuel poverty in Wales was estimated to be 14%. The transition provides an opportunity to reduce levels of fuel poverty, as insulating homes and installing low-carbon heating systems will make homes more energy efficient and we expect electricity prices to fall as renewables deployment progresses.

- We expect the transition to Net Zero to deliver improved health outcomes, through improved air quality, better insulated homes, increased active travel, and healthier diets. There will be some costs of time spent on home retrofits and public transport, and, if a rebound effect (increased driving as a result of lower driving costs) occurs, costs of congestion.

4.2 Economy, businesses, and workers

4.2.1 Economy and businesses

Aggregate impacts of our pathway on the level of Wales' GDP by 2050 are uncertain, but unlikely to be large. However, the economy will be more resilient due to a reduced reliance on internationally traded fossil fuels.

We set out our assessment of economic impacts across businesses and workers in the UK in our Seventh Carbon Budget advice report. Here we highlight the elements that are of particular significance to Wales.

- **Service sectors**: the majority of Wales' GVA is comprised of service sectors (73%).[6] Most businesses and workers in service sectors will not see long-lasting impacts from the transition, although some businesses may need support with upfront costs of transitioning to low-carbon technologies such as heat pumps.

- **Growth sectors**: a growth in jobs in home retrofit will be required. This will require supportive skills policy. There is also the potential to capture opportunities for growth in traded goods, Wales has revealed comparative advantage (RCA) in transport equipment and machinery, which is its largest export (45%), particularly the export of aviation equipment.[7;8] There may be an opportunity to transition some aviation equipment (for example, aircraft engines) to low-carbon equipment. There may also be opportunities for new low-carbon industries, for example, a potential hub for floating offshore wind in Port Talbot.[9]

- **Energy-intensive manufacturing**: manufacturing is a particularly important component of the Welsh economy. Some industrial sectors will face additional costs to eliminate emissions. The Welsh Government should ensure the right incentives are in place for these sectors to switch to low-carbon production and that transitions are planned proactively.

  - Compared to the UK as a whole, manufacturing is a more prominent component of the Welsh economy, comprising 15% of GVA and 10% of employment, compared to 9% of GVA and 7% of employment in the UK.[10;11]

  - A component of this is energy-intensive manufacturing, in particular the production of iron and steel in Port Talbot (see Box 4.1) and the export of oil from Pembrokeshire oil refinery. Mineral fuels are Wales' second largest export (15%), mostly consisting of oil, the export of which will decline with the transition to Net Zero.[12]

  - The other energy-intensive industries (including cement, nickel, and chemicals) span north and south Wales and represent a smaller component of the economy. They face a fundamental transformation to decarbonise their production processes. This will involve some additional upfront and running costs. This requires a supportive investment environment. There is a risk that domestic production is uncompetitive in the short-term as it transitions, which needs to be mitigated through policy, such as a carbon border adjustment mechanism. The development of low-carbon industrial clusters (including the South Wales Industrial Cluster and the Hynet cluster) presents an opportunity to transition these industries.[13] By decarbonising early, manufacturers will be well placed to take advantage of growing global demand for low-carbon goods in the long term.

- **Agriculture.** Wales has an agricultural sector comprising 1.6% of GVA and carrying a wider cultural significance. Our pathway sees an overall decline in livestock herd sizes, with impacts on livestock farming. Farmers will need help to diversify their incomes.

  - We met with farmers in Wales, who highlighted the importance of farming to culture and community, their experience of weather-linked climate change impacts, the need for sufficient incentives, and shared concerns about impacts on jobs and communities. Livestock farmers are already contending with the impacts of climate change on incomes in an industry where, without subsidies, many businesses run a loss.[14] Agriculture has wider importance for the rural economy, communities, and culture, including the Welsh language.

  - Compared to the UK as a whole, agriculture has a slightly more prominent role in Wales' economy. 'Agriculture, forestry, and fishing' comprised 1.6% of GVA, compared to 0.9% across the whole UK. It comprises about 1% of employment in Wales, similar to the UK as a whole. Food and drink manufacturing is slightly more prominent, at 2.3% of GVA compared to 1.6% in the UK.[15]

  - The decline in livestock herd sizes will have impacts on livestock farming and downstream businesses such as abattoirs. Farmers will need help to diversify their incomes, for example through renewables or alternative land management practices (such as woodland creation and peatland restoration). Government financial support will be needed in some cases to ensure appropriate incentives and returns.

- As with emissions-intensive industrial sectors, there may be a case for measures at the UK's border to ensure changes in agricultural production do not simply lead to imports of high-carbon meat and dairy. Our pathway includes a reduction in average UK meat and dairy consumption, which is needed to avoid a reduction in UK livestock being accompanied by an increase in imported meat and dairy.

4.2.2 Workers

Workers are vital to delivering Net Zero. The Welsh Government should plan to enable growth in the sectors that are needed to deliver Net Zero, as well as to support those areas that may be adversely impacted.

- The Welsh Government should publish a Net Zero skills action plan to identify and address barriers to enable growth of the workforces needed to deliver the Net Zero transition.

- They should also work with communities, workers, and local businesses in areas of the economy that may be adversely impacted by the Net Zero transition to develop proactive transition plans that enable access to secure employment and business opportunities.

Box 4.1
Getting ahead of the transition - learning lessons from Port Talbot

The last blast furnace at the Port Talbot steelworks closed in September 2024 - ending the production of primary steel and pig iron at a site which has operated since 1953. Before the closure, manufacture of basic metals represented around 2% of Wales' GVA, while iron and steel represented about 6% of exports.[16;17]

The plant at Port Talbot has been uneconomical for many years, with the plant's owners reporting losses of over £1 million a day, with the blast furnaces nearing the end of their operational life.[18] Strong international competition and high domestic costs have been cited as the reasons why many UK steel plants struggle to be competitive in a global market - with a particular focus on the UK's relatively high industrial energy prices.[19]

Supported by a £500 million investment from the UK Government, the plant's owners are proceeding with plans to invest £1.25 billion to build an electric arc furnace (EAF) at the site by 2027.[20;21] This will allow Port Talbot's long history of steel production to continue, with a production capacity of 3.2 million tonnes - similar to the site's output in recent years, but with an expected emissions footprint up to 90% below that of the blast furnace.[22;23] It also avoids a situation where UK industrial emissions are effectively offshored.

The closure of the blast furnaces will affect to up to 2,800 jobs.[*;24] While at least 500 temporary jobs are expected to be supported during construction of the EAF, it requires far fewer workers to operate - resulting in the permanent loss of 2,100 jobs in the local area once built.[†;25]

Due to the multi-year gap between closure of the previous site and opening of a new one, workers and the wider community face continued uncertainty in the short term. Alternative proposals were put forward by trade unions for a phased closure of the blast furnaces with a view to minimising the economic impact on the local community, but this would have required further investment to extend the life of the blast furnace. The plans were rejected by the plant's owners.

The transition to an EAF, coupled with the continued decarbonisation of UK electricity supply, presents an opportunity for Port Talbot to produce low-carbon steel. This transition can help position the UK steel industry on a more competitive footing going forward, by opening up a growing market for green steel.[26]

Since the closure of the blast furnace, the UK Government announced an £80 million support package for steelworkers to receive grants to start a new business, and a range of grant sizes to support local businesses.[27] A minimum voluntary redundancy package of 2.8 weeks' earnings for each year of service and a paid-for training programme have also been offered by Tata Steel.[28] The opening of the Celtic freeport in 2024 is expected to create up to 11,500 new jobs, although these will not materialise in high numbers yet.[29]

The challenges facing the UK steel sector have been clear for many years and, given the significance of this site to the local economy, a more proactive and decisive transition plan should have been developed for Port Talbot - one which might have considered a wider range of levers that the UK Government has at its disposal and which could have mitigated some of the impacts on the local economy, such as:

- Using policy to improve the attractiveness of investing in green steel in the UK, for example by using product standards to create clear demand signals and taking steps to make UK industrial electricity prices more competitive.
- Convening early and collaborative engagement and negotiations between plant owners, workers, and the community, and being as transparent as possible about the decision-making process.

This could have enabled proactive actions from the Welsh Government to:

- Ensure the right training and re-skilling programmes were in place well before closure.
- Develop a local industrial strategy, working with local authorities, to support alternative employment, including in industries such as heating services and floating offshore wind.

Industry and government must learn lessons from the experience in Port Talbot to guide future efforts to decarbonise other strategically and locally significant emissions-intensive industries, for example around oil refineries such as in Pembroke. There are a limited number of locations in Wales which face such acute risks from the transition, so government should be bolder in intervening to mitigate adverse impacts where the private sector alone is unable to so.

[*] 2,500 redundancies at Port Talbot in 2024, followed by 300 redundancies at Tata Steel's Llanwern site.

[†] Figure of 2,100 refers to direct job impacts in the combined local authorities of Neath Port Talbot Council, Swansea County Council, and Bridgend Council. Further job impacts are expected in supply chains and wider economy.

4.3 The well-being of future generations

The pathway to Net Zero in Wales is well aligned to the other well-being goals under the Well-being of Future Generations (Wales) Act 2015. In Table 4.1, we summarise how our pathway relates to each of its well-being goals.

In line with the Environment (Wales) Act (2016), we also set out here the regard we have given to the most recent Future Trends report and the Future Generations Report:

- The Future Generations Commissioner's first Future Generations Report was published in 2020. The report highlighted climate change as a priority area for Welsh Government policy and gave policy recommendations on both decarbonisation and climate change adaptation, which are summarised in our 2020 advice report, the path to Net Zero and progress on reducing emissions in Wales.[30;31]

- The Future Trends Report was published in 2021. The key findings in the report, and their application to our advice and supporting research, are summarised in Table 4.2 below.

Table 4.1
Interaction between our pathway and the goals in the Well-being of Future Generations (Wales) Act 2015

A prosperous Wales	As discussed in Section 4.2, there will be greater resilience to economic shocks due to a reduced reliance on internationally traded fossil fuels. Impacts on GDP are uncertain, but unlikely to be large. New jobs will be needed in some sectors, such as home retrofit, while a small number of sectors may face higher costs, such as energy-intensive manufacturing, where the Government will need to work with unions, businesses, and workers to ensure attractive alternative sources of employment are available.
A more resilient Wales	
A healthier Wales	We expect the transition to Net Zero to deliver improved health outcomes through improved air quality, better insulated homes, increased active travel, and healthier diets. • The shift to electric cars, modal shift, and to low-carbon heating will improve air quality, with knock-on impacts for health. While impacts will be widespread, they will be particularly felt in urban, densely populated areas, particularly benefitting low-income and marginalised groups. • Provided there are improved public and active travel options, there will be more travel choice, with improved health outcomes from active travel. The biggest health benefits are achieved when people who are not already exercising frequently take up more walking and cycling. • A reduction in average meat and dairy consumption is compatible with a healthy and nutritionally balanced diet and has the potential to bring positive health impacts. The extent of health benefits will depend on what types of meat and dairy are replaced and what they are replaced with.
A more equal Wales	Section 4.1 summarises the overarching findings from our analysis of the impacts on costs and savings for 15 household archetypes as a result of changes to driving and home heating from 2025 to 2050. We reviewed the potential impacts of the Net Zero transition on people with protected characteristics across each of the major sectors, which is explored in more detail in our supporting research Impacts on groups with protected characteristics. There is an opportunity to reduce inequalities, for example through home energy efficiency measures and falling energy bills reducing

A Wales with cohesive communities	fuel poverty and the shift to electric vehicles improving air quality in areas with higher representation of various groups with protected characteristics. However, policy needs to ensure energy efficiency and low-carbon heating measures are accessible and affordable, consider how different groups access flexible energy tariffs, and ensure the provision of charging infrastructure that is accessible to those with disabilities and affordable to those without off-street parking. The Welsh Government should communicate a clear vision to the public about the transition, and engage in meaningful two-way dialogue with communities who may be directly impacted.
A Wales of vibrant culture and thriving Welsh language	Our pathway for Wales includes a reduction in livestock numbers in Wales. As set out in Section 4.2, this does not mean all farmers will need to transition away from livestock, but some farmers will need help to diversify their incomes. Farmers will also need support to adapt to climate change. Responses to our call for evidence highlighted the links between traditional farming in Wales and Welsh language. The Welsh Government should take this into account when supporting farmers to diversify.
A globally responsible Wales	Setting an ambitious and achievable Fourth Carbon Budget, and taking action to achieve Net Zero emissions as soon as possible, shows global leadership in addressing climate change. Wales' Fourth Carbon Budget is set on the basis of territorial emissions. However, there are significant climate benefits to addressing emissions from imports, and Wales can demonstrate leadership by recognising that its impact on the climate extends beyond its territorial boundaries.

Table 4.2
Application of the findings of the Future Trends Report (2021) in our analysis

Theme	Findings	Application in CCC analysis and advice
People and population	Wales is expected to have an ageing population. A steady growth in population is expected, but with variation across regions in Wales. In recent years there has been an increase in net migration from non-EU migrants.	The assumptions we used for our analysis took into account the expected population growth in Wales.
Inequalities	Wales has seen a slight reduction in income poverty levels. Income poverty is more pronounced for people with disabilities and some ethnic minorities. There has been falling unemployment, particularly concentrated in South Wales. Wales has seen an improvement in qualification levels. Links between poverty, poor education, poor health, and poor well-being remain. Wales has lower productivity compared to the UK.	See Section 4.1 on our distributional analysis, which summarises our assessment of how different household archetypes would be impacted by changes to home heating and driving. In our 2023 Net Zero Workforce report, we recognised changing trends in net migration and unemployment might impact on the challenge of ensuring a sufficient and skilled workforce is in place to deliver Net Zero.[32] We have assessed the transition's impact on fuel poverty (see Section 4.1), as well as on groups with protected characteristics, including those with disabilities and ethnic minorities.[33]
Planetary health and limits	It is important for Wales to reduce its greenhouse gas (GHG) emissions. Wales is using natural resources at an unsustainable rate and that consumption is depleting natural	The CCC advises on the GHG emissions targets that Wales should set. Our pathway also includes peatland restoration, woodland creation, and sustainable management, and other measures which would improve the resilience of ecosystems across Wales.

	resources elsewhere. There is also a decline in ecosystem resilience in Wales.	
Technology	Physical and digital technology solutions can help combat climate change. However, there is also a risk of threats to cyber security. Some groups do not have access to digital technologies and services.	In terms of physical technology solutions, our pathway for Wales includes use of a range of low-carbon technologies, such as heat pumps and electric cars. As set out in our supporting research on Impacts on groups with protected characteristics, it will be important for policy makers to consider how to make information on home decarbonisation measures and energy demand flexibility accessible to those who are digitally excluded.

4.4 The state of natural resources

The Environment (Wales) Act 2016 integrated the improvement of environmental issues with the goals of the Well-being of Future Generations (Wales) Act 2015 through the four aims of sustainable management of natural resources (SMNR). These are safeguarded natural resources, resilient ecosystems, a healthy environment for people, and a regenerative economy.

- Progress towards meeting these aims is assessed in the State of Natural Resources Report (SoNaRR), published every five years.
- The Committee has a statutory obligation to give due consideration to the latest version of SoNaRR and its assessment when providing any advice to the Welsh Government on setting or changing its emissions targets or carbon budgets.

The 2020 SoNaRR concluded that Wales is not yet meeting the four SMNR aims, even though some progress has been made towards setting the legal framework for action.[34] Our advice considers this assessment as the latest available, however, a new report is due to be published by the end of 2025. Table 4.3 sets out how the Committee's advice on the Fourth Carbon Budget could contribute to each of the four aims.

Table 4.3
Interaction between the SMNR aims and the Balanced Pathway

Stocks of natural resources are safeguarded and enhanced	The transition towards Net Zero will increase the capacity of the land to store carbon, along with co-benefits for other priorities for the natural environment. • Sustainable agricultural practices on arable and grazing land will offer resource protection benefits for air, water, and soil quality alongside direct emissions reduction. • The sustainable management of broadleaves has benefits for biodiversity as well as climate change mitigation. • Increasing woody vegetation on-farm via agroforestry and hedgerow management will support soil protection and mitigate impacts from agricultural run-off. • The rewetting and restoration of peatlands will help protect organic soils, support specialised wetland habitats, and provide benefits for water quality and regulation.
Ecosystems are resilient to expected	Measures in our pathway can build ecosystem resilience, helping them to adapt in the face of future climate change.

and unforeseen change	• Woodland measures align to the UK Forestry Standard, including sustainable management, advocating for a mix of species and providing open space for biodiversity. • Appropriate siting of new woodland, trees, and hedgerows can enhance biodiversity on-farm and increase connectivity of habitats. • Rewetting and restoration of peatlands builds resilience to flooding, wildfires, and climate change.
Wales has healthy places for people, protected from environmental risks	Measures that protect natural resources and build ecosystem resilience will help provide healthy places for communities to work and live. • Trees sited appropriately in urban and peri-urban settings can support improved air quality and help Welsh cities adapt to extreme weather events such as heat waves. They will also offer additional recreational services, such as easier access to nature. • New woodlands and peatland restoration can support natural flood management alongside hard infrastructure approaches, helping to protect downstream communities. • Well-designed measures to encourage the use of public transport and active travel (along with the relevant infrastructure) will promote healthier lifestyles and can improve connectivity between communities. Widespread uptake of zero-emission vehicles will deliver improvements in air quality and noise reduction. • Building on Wales' strong record in recycling and waste prevention can reduce emissions and improve resource efficiency, as well as supporting delivery of other environmental goals.
A regenerative economy	The cross-economy measures proposed in our pathway will help build and sustain an efficient, innovative low-carbon regenerative economy that maximises the value and use of Wales' natural resources. • Moving towards low-carbon sources of energy production will support decarbonisation across the economy and the decoupling of economic growth from dependence on fossil fuels and their environmental impacts. • Sustainable agriculture and low-carbon farming can offer cost-saving benefits, alongside reducing environmental impact and GHG emissions from the agriculture sector. • Natural climate approaches such as woodland creation and nature restoration offer opportunities for new income streams and business diversification in the agriculture sector. • Moving towards a more circular economy whereby resources are diverted from waste and repurposed for production of goods will help build a more efficient and self-sufficient economy and optimise the use of valuable natural resources without depleting them. • The Net Zero transition will provide opportunities for new or expanding green industries and will promote innovation to decarbonise in existing industries.

Endnotes

[1] Office for National Statistics (2024) *Main fuel type or method of heating used in central heating, England and Wales*. https://www.ons.gov.uk/peoplepopulationandcommunity/housing/datasets/mainfueltypeormethodofheatingusedincentralheatingenglandandwales.

[2] Wales Centre for Public Policy (2023) *How could Wales feed itself in 2035? Evidence Pack*. https://www.wcpp.org.uk/wp-content/uploads/2023/07/How-could-Wales-feed-itself-in-2035.pdf.

[3] Office for National Statistics (2023) *Towns and cities, characteristics of built-up areas, England and Wales*. https://www.ons.gov.uk/peoplepopulationandcommunity/housing/articles/townsandcitiescharacteristicsofbuiltupareasenglandandwales/census2021.

[4] National Centre for Social Research (2024) *Car Ownership: Evidence Review*. https://assets.publishing.service.gov.uk/media/6781339100e3d719f19217f1/dft-car-ownership-evidence-review.pdf.

[5] Office for National Statistics (2023) *Housing, England and Wales: Census 2021. Figure 6*. https://www.ons.gov.uk/peoplepopulationandcommunity/housing/bulletins/housingenglandandwales/census2021#housing-england-and-wales-data.

[6] Office for National Statistics (2024) *Regional gross value added (balanced) by industry: all ITL regions*. https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/nominalandrealregionalgrossvalueaddedbalancedbyindustry.

[7] Welsh Government (2020) *Export Action Plan for Wales*. https://www.gov.wales/sites/default/files/publications/2020-12/export-action-plan.pdf.

[8] Welsh Government (2020) *Export Action Plan for Wales*. https://www.gov.wales/sites/default/files/publications/2020-12/export-action-plan.pdf.

[9] Marine Energy Wales (no date) *Port Talbot Floating Offshore Wind Hub one step closer to UK Gov FLOWMIS support*. https://www.marineenergywales.co.uk/industry-news/port-talbot-floating-offshore-wind-hub-one-step-closer-to-uk-government-flowmis-support/.

[10] Office for National Statistics (2024) *Regional gross value added (balanced) by industry: all ITL regions*. https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/nominalandrealregionalgrossvalueaddedbalancedbyindustry.

[11] Office for National Statistics (2024) *JOBS05: Workforce jobs by region and industry*. https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/workforcejobsbyregionandindustryjobs05.

[12] Welsh Government (2024) *Welsh international goods trade: July 2023 – June 2024*. https://www.gov.wales/welsh-international-goods-trade-july-2023-june-2024-headline-data-html#:~:text=The%20EU%20accounted%20for%2058.6,the%20year%20ending%20June%202023.

[13] Net Zero Industry Wales (no date) *Welsh Industrial Clusters*. https://nziw.wales/welsh-industrial-clusters/#:~:text=These%20are%20the%20South%20Wales,Cluster%20and%20Deeside%20Decarbonisation%20Forum.

[14] Welsh Government (2024) *Farm incomes, April 2023 – March 2024*. https://www.gov.wales/farm-incomes-april-2023-march-2024-html.

[15] Office for National Statistics (2024) *Regional gross value added (balanced) by industry: all ITL regions*. https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/nominalandrealregionalgrossvalueaddedbalancedbyindustry.

[16] Welsh Government (2023) *Welsh International Goods Trade: October 2023 to September 2024 (headline data)*. https://www.gov.wales/welsh-international-goods-trade-october-2023-september-2024-headline-data-html.

[17] Office for National Statistics (2024). *Regional gross value added (balanced) by industry: all ITL regions - Office for National Statistics*. https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/nominalandrealregionalgrossvalueaddedbalancedbyindustry.

[18] HM Government (2024). *Tata steel Q and A (accessed January 2024)*. *https://www.gov.uk/government/news/tata-steel-port-talbot-steelworks-qa*.

[19] House of Commons Library (2024) *UK steel industry statistics and policy*. *https://researchbriefings.files.parliament.uk/documents/CBP-7317/CBP-7317.pdf*.

[20] HM Government (2024). *Press release on funding for Port Talbot steel workers*. https://www.gov.uk/government/news/uk-government-increases-funding-for-port-talbot-steel-communities. (Accessed January 2025).

[21] BBC News (2024). *Tata's electric arc furnace plans submitted*. https://www.bbc.co.uk/news/articles/c4gxzvr5n3no#:~:text=Metals%20and%20mining%20solution%20company,by%20the%20end%20of%202027.

[22] Tata Steel UK (2023). *Green steel future: Our plan to transform the UK business*. https://www.tatasteeluk.com/green-steel-future. (Accessed January 2025).

[23] Turley for Tata Steel UK (2024). *Port Talbot EAF Planning Application*. https://www.tatasteeluk.com/sites/default/files/planning-statement---eaf.pdf.

[24] UK Government (2024) *Government puts workers at the heart of new and improved Port Talbot deal*. https://www.gov.uk/government/news/government-puts-workers-at-the-heart-of-new-and-improved-port-talbot-deal.

[25] Turley for Tata Steel UK (2024). *Port Talbot EAF Planning Application*. https://www.tatasteeluk.com/sites/default/files/planning-statement---eaf.pdf.

[26] Bloomberg New Energy Finance (2023) *Green Steel Demand is Rising Faster Than Production Can Ramp Up*. https://about.bnef.com/blog/green-steel-demand-is-rising-faster-than-production-can-ramp-up/.

[27] UK Government (2024) *UK Government increases funding for Port Talbot steel communities*. https://www.gov.uk/government/news/uk-government-increases-funding-for-port-talbot-steel-

communities#:~:text=An%20%C2%A380%20million%20support,Steel%27s%20move%20to%20greener%20steel making.

[28] UK Government (2024) *Government puts workers at the heart of new and improved port talbot deal*. https://www.gov.uk/government/news/government-puts-workers-at-the-heart-of-new-and-improved-port-talbot-deal.

[29] HMG (2024) *Celtic Freeport 'Open for Business'*. https://ukfreeports.campaign.gov.uk/celtic-freeport-open-for-business/.

[30] Climate Change Committee (2020) *Advice Report: The Path to a Net Zero Wales*. https://www.theccc.org.uk/wp-content/uploads/2020/12/Advice-Report-The-path-to-a-Net-Zero-Wales.pdf.

[31] Future Generations Commissioner for Wales (2020) *The Future Generations Report*. https://www.futuregenerations.wales/wp-content/uploads/2020/05/FGC-Report-English.pdf.

[32] Climate Change Committee (2023) *A Net Zero Workforce*. https://www.theccc.org.uk/publication/a-net-zero-workforce/.

[33] Climate Change Committee (2025) *Impacts of the Seventh Carbon Budget on groups with protected characteristics*. https://www.theccc.org.uk/publication/impacts-on-groups-with-protected-characteristics.

[34] Natural Resources Wales (2020) *State of Natural Resources Report (SoNaRR)*. https://naturalresources.wales/evidence-and-data/research-and-reports/state-of-natural-resources-report-sonarr-for-wales-2020/?lang=en.

Annex 1: Priority recommendations

Table A1.1 Priority recommendations to the Welsh Government

Sector	Recommendations
Fourth Carbon Budget	• Set the Fourth Carbon Budget at an annual average of 73% below the 1990 baseline for the period from 2031 to 2035. The Welsh Government should plan to meet it through domestic action without using international credits. • As part of the report setting out the Welsh Government's proposals and policies for meeting the Third Carbon Budget, include an assessment of the longer-term actions that are needed to get Wales on track for the Fourth Carbon Budget and beyond.
Cross-cutting	• Work with the UK Government to develop and implement an engagement strategy to provide clear, trusted information about the most effective actions for households and businesses in Wales to reduce emissions and the benefits of low-carbon choices, signposting to available sources of advice and support. • Publish a Net Zero skills action plan to identify and address barriers to enable growth of the workforces needed to deliver the Net Zero transition. • Work with communities, workers, and businesses in areas of the economy that may be adversely impacted by the Net Zero transition to develop proactive transition plans that enable access to secure employment and business opportunities.
Industry	• Continue to work with the UK Government to support the development of plans to develop carbon capture and storage (CCS) and hydrogen in the South Wales Industrial Cluster and the HyNet cluster.
Agriculture and land use	• Provide incentives and address barriers for farmers and land managers to diversify land use and management into woodland creation, peatland restoration, agroforestry, and renewable energy. These policies need to support and empower rural communities to deliver these changes. • Provide long-term certainty on public funding for farming practices and technologies which reduce emissions from managing crops and livestock. As part of this, ensure low-regret and low-cost measures are taken up through regulations or minimum requirements in agricultural support mechanisms, especially when they can deliver efficiency improvements.
Surface transport	• Expand provision of charging infrastructure and provide reliable public information to support the successful implementation of the ZEV mandate. • Improve Wales' public transport and active travel infrastructure through strategic investment in integrated networks enhanced services, and dedicated walking and cycling routes, supported by long-term funding and powers for local councils.
Buildings	• Put in place requirements on housing developers ensuring no new properties completed from 2026 use fossil fuel heating systems. Deliver changes to Building Regulations with stringent transition arrangements which ensure that, from 2026, all new homes are built with low-carbon heating systems. • Introduce regulations to ensure that, beyond 2035, all new and replacement heating systems installed are low carbon. • Support improvements to home energy efficiency, particularly in social housing, and provide targeted support to ensure that poorly insulated homes are not a barrier to uptake of low-carbon heating systems for low-income households.

	• Introduce a comprehensive multi-year programme for decarbonisation of public sector buildings. This should set out strategic plans for when best to take the required decarbonisation actions in buildings across the public estate and should be supported by long-term capital settlements.
Waste	• Introduce policies that deliver ambitious recycling and waste reduction goals, building on Wales' strong record on recycling. • Prevent energy from waste capacity expansion unless a viable route to connecting CCS can be established.

May 2025

Wales' Fourth Carbon Budget

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