HM Treasury

# Net Zero Review

## Analysis exploring the key issues

October 2021

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ISBN 978-1-911686-31-6
PU 3161

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# Executive summary

## Overview

Global action to mitigate climate change is essential to long-term UK prosperity. The majority of global GDP is now covered by net zero targets. As the world decarbonises, UK action can generate benefits to businesses and households across the country.

The UK has been at the forefront of global action to tackle climate change and has led the way by decarbonising its economy faster than any other G7 country. In 2019, the UK became the world's first major economy to adopt a legally binding target to reduce its greenhouse gas emissions to net zero by 2050. The transition to net zero will mean changes in the way businesses run and people live in England, Scotland, Wales and Northern Ireland by 2050, which will be different for everyone based on their individual circumstances. Some of these changes are known, but there remain areas of significant uncertainty over a 30-year transition, with major system-wide decisions to be taken over the next decade on the UK's future energy mix and the role of negative emission technologies in achieving net zero.

The Net Zero Review is an analytical report that uses existing data to explore the key issues and trade-offs as the UK decarbonises, against a backdrop of significant uncertainty on technologies and costs, as well as changes to the economy over the next thirty years. It is not a cost-benefit analysis but a first step in understanding trade-offs over a 30-year economic transition. It considers the potential exposure of businesses and households to the transition, and highlights factors to be taken into account when designing policy that will allocate costs over this time horizon so that policy can help to make the most of opportunities that will arise, and support households as necessary. The Net Zero Strategy sets out a comprehensive range of policies to support and capitalise on the UK's transition to net zero by 2050 across the whole economy[1].

Overall, a successful and orderly transition for the economy could realise more benefits – improved resource efficiency for businesses, lower household costs, and wider health co-benefits – than an economy based on fossil fuel consumption.

## The risks from climate change are substantial

Climate change is already affecting the UK. The average temperature in the UK between 2008 and 2017 was 0.8°C higher than in the period from 1961 to 1990. The UK has experienced several extreme weather events in recent decades. These include significant flood events in England in the winters of 2013-14 and 2015-16 and the joint hottest summer on record in 2018, with temperatures equalling the summers of 2006, 2003 and 1976. There are 240,000 homes and properties currently

[1] 'Net Zero Strategy', BEIS, 2021.

in high flood risk areas, and if shoreline management plans are not implemented, 5,000 properties could be affected by coastal erosion over the next twenty years as sea levels rise and more wave energy reaches the coast.[2]

The impacts of climate change across the world are even more significant. Average global temperatures are 1°C higher than in the 1850s, and global sea levels have risen by 16 centimetres since 1902. Arctic sea ice is already 65% thinner than in 1975.[3] The number of natural catastrophes has consequently been rising, from an average of 292 events a year in the 1980s to 689 per year in the 2010s.[4]

## The UK is leading global action to reduce emissions

Between 1990 and 2019, the UK reduced its greenhouse gas emissions by 44%, compared to 5% for the G7 as a whole. At the same time, the UK economy grew by almost 80%.[5] The rate of reduction in the carbon intensity of the UK economy since 2000 has also been the fastest in the G20.[6]

Building on this significant progress to date, the UK is hosting the UN Climate Change Conference with Italy in 2021 (COP26) to bring together world leaders to commit to urgent global climate action. This will aim to secure emissions reduction commitments that put us on a path to achieving the objectives of the historic agreement made in Paris in 2015, where world leaders agreed to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the rise to 1.5°C. It is implicit in this target that global greenhouse gas emissions should reach net zero by the second half of this century.[7]

## The UK is the first major economy to set a legally binding net zero target

### The Climate Change Committee recommendations

Following the Paris Agreement, the UK, Scottish and Welsh governments asked the Climate Change Committee (CCC) for advice on setting a net zero greenhouse gas emissions target.[8] In May 2019, the CCC published its recommendation that the UK could reach net zero by 2050, with individual targets for Scotland and Wales.[9] Later

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2 'Climate change impacts and adaptation report', Environment Agency, 2018.

3 'Effects of climate change', Met Office, accessed 12 April 2021.

4 Calculated from number of relevant loss events by peril 1980-2019 in 'Risks posed by natural disasters', MunichRe, accessed 12 April 2021.

5 'GDP, PPP (constant 2017 international $)', World Bank, https://data.worldbank.org/indicator/NY.GDP.MKTP.PP.KD; 'GHG emissions with LULUCF', Emissions figures exclude IAS, UNFCCC https://di.unfccc.int/time_series

6 'The Low Carbon Economy Index 2019', PwC, 2019.

7 'Paris Agreement', United Nations, 2015.

8 'UK climate targets: letter to the Climate Change Committee (CCC) – 15 October 2018', Department for Business, Energy & Industrial Strategy (BEIS), Welsh Government and Scottish Government, October 2018. Northern Ireland does not currently have its own climate change legislation or emissions targets, but emissions from Northern Ireland are still covered by the wider UK target.

9 'Net Zero: The UK's contribution to stopping global warming', CCC, 2019.

that year, the UK became the first major economy to implement a legally binding net zero target.[10]

Alongside its advice on reaching net zero by 2050, the CCC recommended that HM Treasury undertakes a review of "how the costs of achieving net zero emissions are distributed and the benefits returned… the fiscal impacts, risks of competitiveness effects and the impacts of decarbonisation across the whole economy" and "the full range of policy levers, including carbon pricing, taxes, financial incentives, public spending, regulation and information provision."[11]

## Net Zero Review

HM Treasury agreed to conduct a review into the issues raised by the transition to net zero, and published Terms of Reference in November 2019. An interim report was published in December 2020, which set out initial analysis on the key issues and trade-offs over the course of the transition.

This final report considers the potential macroeconomic effects of the transition; the potential economic opportunities and risks of the transition; the factors affecting a household's exposure to the transition; the policy levers that could support the transition; and the likely fiscal implications of the transition. The analysis uses the Carbon Budget 6 trajectory and will change over time as the UK continues to decarbonise. HM Treasury is also updating its governance, processes and capabilities to support the transition to net zero; for example, the government has updated the carbon values used as part of Green Book policy appraisal and evaluation. Details can be found at the end of this report.

The Review forms part of a cross-government effort to set the UK on a path to achieving net zero, and informs the Net Zero Strategy, as well as future policy across government.

# Net Zero Review's Final Report

### Current economic analysis could understate the economic cost to the UK as the climate heats up. UK climate action could provide a boost to the economy; the required investment could contribute to growth. There will also be co-benefits, such as improved air quality.

The costs of global inaction significantly outweigh the costs of action. Higher temperatures and an increased prevalence of extreme weather events could lead to reduced productivity growth in the UK and significant damage to UK capital stock. Most studies do not reflect the economic impact of indirect effects and global spillovers; for example, damage to global supply chains affecting trade, reduced production in trading partner nations pushing up the cost of imported goods, and changes to migration from regions heavily affected by climate change. The true cost of a warmer climate to the UK economy could be higher than current estimates.

[10] 'UK becomes first major economy to pass net zero emissions law', BEIS, 2019; Climate Change Act 2008 (2050 Target Amendment) Order 2019.

[11] 'Net Zero – The UK's contribution to stopping global warming', CCC, 2019.

In recognition of the risks to the UK and other countries, the UK became the first major economy to implement a legally binding net zero target in 2019. The majority of global GDP is now covered by net zero targets. [12]

The step change in investment required to reach net zero could provide a boost to the UK's economy, but will contribute to structural change as resources and jobs move from high to low carbon industries. The transition requires households and businesses across the UK to make changes. For example, insulating homes and business premises; installing low carbon heat sources; replacing petrol and diesel vehicles with zero emission equivalents; and addressing the emissions from necessary industrial processes. One of the most significant changes over the next decade will be the UK's future energy mix. Changes present significant opportunities for businesses and benefits for consumers as new markets grow and costs fall over time. There will be new green jobs amidst changes to the labour market, as considered in the interim report and discussed in the Net Zero Strategy.

There will also be significant co-benefits, such as cleaner air. Improved air quality could deliver £35 billion worth of economic benefits in the form of reduced damage costs to society, reflecting for example lower respiratory hospital admissions. [13] Where these benefits allow for a healthier and more productive workforce, they can support long-term growth and productivity improvements.

Ultimately, the way in which the economy and policy respond to the changes required over the next thirty years, will determine the scale, distribution and balance of opportunities and challenges. The government's work in preparing this Review and the Net Zero Strategy has looked at how to maximise these opportunities.

## The UK is integrated in the global economy; there are opportunities to build on UK strengths but risks in some high-emission and trade-exposed sectors

Climate change is a global problem, and the UK is an open economy. International cooperation will be essential to avoid catastrophic climate change, and global decarbonisation choices present new opportunities for UK firms.

The main export opportunities for the UK are likely to be in areas that build on established UK strengths. Integration in global value chains means the UK will also benefit from low carbon innovation and products in other countries.

Climate action in the UK can lead to economic activity moving abroad if it directly leads to costs increasing such that it is more profitable to produce in countries with less stringent climate policies. This would undermine the objective of reducing emissions. However, the main risks are concentrated in a small number of sectors, and primarily in these sectors' export activities rather than domestic ones. As such, the first best solution is effective international co-operation and policy co-ordination.

## Household characteristics drive a household's exposure to the net zero transition

As with all economic transitions, ultimately, the costs and benefits of the transition will pass through to households through the labour market, prices and asset values.

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[12] 'Taking stock: A global assessment of net zero targets', University of Oxford and ECIU, 2021.

[13] 'Impact Assessment for the sixth carbon budget', BEIS, 2021.

These costs and benefits will not fall evenly across households. It is not possible to forecast how individual households will be affected over the course of an economic transition that is expected to take thirty years to complete. The Net Zero Review interim report sets out how households might be affected by the transition through their employment (replicated at Annex B). This report outlines the factors that could affect consumer prices.

There is significant uncertainty over the precise mix of technologies and their costs, and household incomes will rise over the next thirty years. However, recent carbon consumption patterns can help to develop a provisional picture of which households could be most exposed in the transition, and which may face the highest costs. At an aggregate level, higher income households consume three times more carbon than lower income households in absolute terms, and lower income households spend a higher share of their income on high carbon goods. However, there is substantial variation within income groups driven by factors such as how much energy they use, the type of house they live in, and whether they drive a car; these factors will have a significant influence over a household's overall exposure to the transition.

Given the significant variation within income groups, it will be more effective to focus on individual technology transitions, with taxpayers providing targeted capital support for those low-income groups most acutely affected by a specific technology transition (and in advance of policies that penalise or phase-out use of high carbon technologies), than to consider the transition in aggregate and develop universal and untargeted policies to support households – such as, changes to tax and welfare. This would also mean that low-income groups could benefit sooner from the household savings that arise from a transition.

## Within each technology transition, there are a range of factors that affect the degree to which a household could be exposed to costs, and how soon they could experience the benefits of the new, low carbon economy

Households will experience changes to the technologies they use in their everyday lives – the nature of the energy they consume, how they heat their home, and the type of car or van that they drive. Within each technology transition, there are a range of factors that will affect the degree to which a household is exposed to the transition, the level of capital outlay required, and how soon a household could start to see changes in their running costs.

Exposure to power decarbonisation costs will depend on the unit price of electricity as well as energy consumption over a broader range of activities in the future – both of which are uncertain over a 30-year time horizon. Reliance on fossil fuel imports results in exposure to international energy market trends, which can lead to volatility in the unit price of electricity. Expansion of UK renewables will, therefore, provide greater stability and resilience in the future.

Households' exposure to housing decarbonisation will depend on a number of factors, including dwelling size and dwelling type. For example, larger houses are more likely to face higher costs. Households living in social housing may be less exposed to costs as social housing is on average already much better insulated, with 62% of dwellings already having wall insulation, compared to just 32% of privately rented dwellings. Capital support is available to support low-income groups through the Boiler Upgrade Scheme, the Homes Upgrade Grant and the Social Housing

Decarbonisation Scheme. The government is also working with industry to halve the upfront cost of new technology, such as heat pumps, by 2025, and achieve parity with fossil fuel boilers by 2030.

Current pricing of electricity and gas does not incentivise households to switch from gas boilers to electric heat pumps, as it affects the level of household savings possible. Expanding carbon pricing to gas and reducing policy costs in electricity bills would improve price incentives. The Heat and Buildings Strategy[14] confirms that the government will look at options to shift or rebalance energy levies (such as, the Renewables Obligation and Feed-in Tariffs) and obligations (such as, the Energy Company Obligation) away from electricity to gas over this decade. This will include looking at options to expand carbon pricing and remove costs from electricity bills while limiting any impact on bills overall. A Fairness and Affordability Call for Evidence will be launched, with a view to taking decisions in 2022.

The total cost of Electric Vehicle (EV) ownership will depend on future government policy and factors such as the price of the vehicle, access to finance, usage, maintenance costs, and the cost of charging. Car usage and maintenance costs, in particular, will affect how soon savings from the transition to EVs will materialise. Policies to support the adoption of EVs may disproportionately benefit higher income groups, and the costs of any policies that affect the remaining drivers may fall disproportionately on low-income groups; this could create a trade-off in some areas between incentivising decarbonisation and minimising distributional impacts.

This analysis reflects the complex nature of the transition to net zero, and the range of issues that will need to be considered when designing policy in the future.

## Policy to support the transition can help make the most of the opportunities and keep costs down

Multiple policy instruments will be needed to address multiple market failures as businesses and households transition from high carbon technologies to low carbon ones. The policy instruments used to facilitate the transition can reduce the magnitude of transition costs and affect the distribution of them across businesses and households. The successful growth of the EVs market has shown the role that policy can play to support market expansion as well as bring down costs for households.

Competitive markets are likely to deliver the most efficient transition across the economy. Widespread and increasing carbon prices can create a strong incentive for the private sector to invest and innovate, while giving firms flexibility as to how to abate emissions. The UK has committed to exploring UK Emissions Trading Scheme (UK ETS) expansion to the two-thirds of uncovered emissions. Well targeted and designed regulation will continue to have a central role in reducing emissions and can be an effective tool where demand is not responsive to changes in price. It can also benefit consumers through more efficient products and standards. In some cases, public spending can also help to overcome other market failures that could hinder a successful transition and play a role in mitigating acute distributional impacts. Overall, a combination of tax, regulation, spending and other facilitative levers will be required.

[14] 'Heat and Buildings Strategy', BEIS, 2021.

Alongside this, innovation will be vital in the 2020s, and policy can support private investment to ensure the UK increases the pace of decarbonisation, and has access to new cost-effective technologies. It will be essential for the UK to maintain technology optionality over this decade, but this should be balanced against the risk of stranded assets.

## The transition has implications for current and future taxpayers

The transition has material fiscal consequences. These arise alongside wider long-run pressures to the public finances and will need to be managed in order to maintain fiscal sustainability.

There will be demands on public spending, but the biggest impact comes from the erosion of tax revenues from fossil fuel-related activity. Any temporary revenues from expanded carbon pricing are unlikely to be sufficient to offset the structural decline in tax revenues, but will be important in supporting the transition and can help manage any demands for public spending to support the transition. If there is to be additional public spending, the government may need to consider changes to existing taxes and new sources of revenue throughout the transition in order to deliver net zero sustainably, and consistently with the government's fiscal principles. Seeking to pass the costs onto future taxpayers through borrowing would deviate from the polluter pays principle, would not be consistent with intergenerational fairness nor fiscal sustainability, and could blunt incentives. This could also push up the economic cost of the transition.

# Chapter 1

# Net Zero and the UK economy

Global action to mitigate climate change is essential to long-term UK prosperity, productivity and competitiveness.

The UK has already made good progress in decarbonising the economy while also delivering growth. The transition to net zero implies a significant transformation of the UK economy over the next three decades. The overall impact is uncertain and challenging to estimate. Existing estimates suggest that the impact on GDP by the end of the transition is likely to be relatively small, and dwarfed by the costs of global inaction. The economic impact will be uneven across the economy. The scale of the change for some businesses, sectors and regions is likely to be substantial. Ultimately, this will depend on policy decisions and how the economy responds.

Notably, higher levels of investment will be required to adapt infrastructure, businesses, homes and transport for an economy powered by clean energy rather than fossil fuels.

Significant structural change implies benefits and costs. There will be opportunities for innovation, employment and investment, which will bring growth to many businesses and lower costs for many consumers by the end of the transition. There will also be health and wellbeing improvements as a result of changes to air and water quality and biodiversity. Overall, a successful and orderly transition for the economy could realise more benefits – lower household costs, improved resource efficiency for businesses, wider health co-benefits – than an economy based on fossil fuel consumption.

## Overview

1.1 Global action to mitigate climate change is essential to long term prosperity. In 2006, HM Treasury commissioned the Stern Review of the Economics of Climate Change. This estimated the overall costs and risks of global warming to be equivalent to losing between 5% and 20% of global GDP each year. [1]

1.2 Estimates of economic costs from climate change damage have large bands of uncertainty and results depend on modelling approach and which economic factors are included and omitted. While a broad range of research

[1] 'Stern Review: The Economics of Climate Change', HM Treasury, 2006.

is valuable to build the evidence base on this important topic, identifying the scope and limitations is important for considering policy implications.

## Table 1.A: Physical Risks Modelling Approaches

| Impacts covered | Caveats | Example(s) |
|---|---|---|
| Chronic impacts or acute impacts | Captures only one type of physical risk, likely understating the full range of economic costs from climate change. | • (International Monetary Fund, 2019) [2] *chronic impacts only* |
| Chronic & acute impacts | Provides a view of how both types of direct physical risks are likely to combine to impact economies. However, does not capture the impact on economic channels exposed to indirect impacts, for example trade, migration, and prices. | • (OECD, 2015) *Does capture some indirect impacts but does not quantitatively model the full range.*<br>• (European Central Bank, 2021)[3] |
| Chronic & acute & indirect impacts | Captures the direct and indirect economic impacts from climate change. However, often requires key assumptions, proxies, and simulations to be made to reflect the complex and diverse range of impacts in one model. | • (Swiss Re, 2021) |
| Economic impact from tipping point climate events | The true cost of extreme physical risks can only be captured by also considering the possibility of 'tipping point' events occurring, such as ice sheet collapse. Economic impacts from these events are expected to be extreme but predicting the scale and probability with certainty is challenging, they are consequently often ignored or given a highly stylized treatment that fails to accurately represent geophysical dynamics.[4] | • (Dietz. S et al, 2021) |

1.3 There is evidence that while the UK might be less exposed to physical risks of continued global warming than many other nations owing to its temperate climate and status as an advanced economy,[5] there are potentially still

[2] 'Fiscal Monitor: How to mitigate climate change', IMF, 2019.

[3] 'Climate related risk and financial stability', European Central Bank, 2021.

[4] 'Economic impacts of tipping points in the climate system', Dietz. S et al, PNAS, 2021.

[5] Advanced economies are more likely to be able to afford and deploy effective adaptation technology to limit some negative economic impacts from climate deterioration.

significant indirect impacts. For example, damage to global supply chains affecting trade, reduced production in trading partner nations pushing up the cost of imported goods, or changes to migration from regions heavily affected by climate change. This highlights the UK economic incentive for encouraging global action towards the Paris Agreement target. The OECD highlight that rising sea levels and temperatures and extreme weather can disrupt trade and constrain the supply of imported goods.[6] A 2013 academic review of climate economic modelling found they estimated a mean 20% increase in average agricultural producer prices by 2050 in a 4°C warming scenario trajectory. [7] These pressures could increase the prices of certain imported UK goods from trade partners more directly exposed to climate change.

1.4 Direct impacts from increased temperatures and an increased prevalence of extreme weather events could also lead to reduced productivity growth and significant damage to UK capital stock. IMF has projected a potential loss to UK GDP of 4% by 2100 from reduced labour productivity due to increased temperatures in a 4°C warming scenario.[8] CCC highlights that expected damage from flooding to UK non-residential buildings alone average approximately £670 million annually and could rise by 80% by 2080 in a 4°C warming scenario. Costs from flooding across all property types will be larger than this. The 2015-2016 floods for example, were estimated to cost £1.6 billion to the UK economy.[9] Damage to UK infrastructure can reduce economic growth, including by diverting potential productive investment elsewhere in the economy towards replacing or repairing damaged capital stock.

1.5 When considered fully to reflect the impact of indirect effects and global spillovers, the cost to the UK economy in the absence of mitigation would be higher than those studies which only capture direct domestic impacts. A Swiss Re assessment of a wide range of direct and indirect impact channels, also simulating for unknown future impacts, projects between a 3.1% – 8.7% loss to UK GDP by 2050 in their severe 2.6°C-3.2°C warming scenario.[10]

1.6 In recognition of the risks to the UK and other countries, the UK became the first major economy to implement a legally binding net zero target in 2019. This also aligns the UK's domestic framework with the objectives of the Paris Agreement.

## Net economic impact in 2050 of the transition

1.7 The eventual net impact of the transition on output is highly uncertain and challenging to estimate. It will depend on the policies used to catalyse the change and technological progress that has not yet occurred. Efforts to quantify this impact can vary depending on factors such as the choice of model and counterfactual, however, most suggest the impact on output in

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6 'International trade consequences of climate change', OECD Trade and Environment Working Papers, 2017.

7 'Climate change effects on agriculture: Economic responses to biophysical shocks' Nelson et al, PNAS, 2013.

8 'Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis', The IMF, 2019.

9 'Independent Assessment of UK Climate Risk', CCC, 2021.

10 'The economics of climate change: No action not an option', Swiss Re, 2021.

2050 is likely to be small relative to total growth over the period.[11][12][13] This was discussed in greater detail in the interim report.

1.8 These studies tend not to compare the costs and benefits of the net zero transition to the costs of unmitigated climate change, and while the costs of global inaction are significant, the unmitigated costs would also be an unsuitable counterfactual for UK policy analysis: global action will be necessary to prevent these costs from materialising, and a disproportionately costly counterfactual could mask differences in the economic and distributional implications of decarbonisation policy choices. Instead, focusing on the economic impacts that result from UK decarbonisation policy choices should highlight the opportunities, costs and trade-offs of playing a leading role compared to free riding in the global transition.

## Economic opportunities during the transition

1.9 The significant economic structural change underlying the transition will present a challenge to policy makers, businesses and households. Learning lessons from previous major transitions, it will be essential to understand the potential exposure to opportunities and challenges in order to design policies to enhance economic benefits and reduce costs across the country.

1.10 Reaching net zero will involve some costs. Policies needed to drive investment and behaviour change can lead to an upwards pressure on consumer prices of goods and services that are more carbon-intensive and can weaken the profitability of the companies that produce them. This shift in relative prices and impact on demand, as well as higher costs of supply, is likely to bring major structural changes in the economy as existing industries adjust or face decline.

1.11 However, the transition to net zero will also create new opportunities for growth. A step change in investment and the creation of new markets can catalyse innovation and lead to productivity growth, as discussed below. As the world moves to meet the Paris agreement commitments, the UK could build on existing areas of comparative advantage to generate new low carbon, high-value jobs and export opportunities. The UK has an opportunity to establish itself as a global leader in specific activities across the future green global economy. This is discussed further in chapter 2. A recent study conducted by a non-governmental consortium, led by Vivid Economics,

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[11] European Commission analysis of a net zero-equivalent scenario (1.5˚C global warming) found an impact on EU GDP to 2050, ranging from slightly negative to slightly positive (-0.63% to +1.48% depending on the model choice. 'In-depth analysis in support on the COM(2018) 773: A Clean Planet for all – A European strategic long term vision for a prosperous, modern, competitive and climate neutral economy', European Commission, 2018.

[12] The analysis the CCC commissioned to accompany their 2019 net zero recommendation similarly suggested a moderate impact on the UK's GDP in 2050 (-0.8% or +3.4% according to model choice). 'Report to the Climate Change Committee (CCC) of the Advisory Group on costs and benefits of net zero', CCC, 2019.

[13] More recent analysis is also mixed: some studies find positive GDP impacts, such as 'Economic impact of the sixth carbon budget', Cambridge Econometrics, 2020; others find more negative GDP impacts, such as 'Macroeconomic responses consistent with the NGFS scenarios' National Institute of Social and Economic Research workshop, 2020.

estimates that strong and sustained innovation in twelve key low carbon sectors could contribute £27 billion to the economy through domestic economic activity and £26 billion through exports by 2050.[14]

1.12 The expansion of green energy generation can reduce the UK economy's vulnerability to fossil fuel price volatility. Evidence from the Bank of England suggests that the UK has become more exposed to oil supply and demand shocks since the mid-2000s, when the UK became a net importer of oil.[15] UK is also a net importer of gas.[16] An expanded green energy sector can help to mitigate this but will require sufficient energy storage solutions in order to address energy security concerns. There are also wider potential economic benefits from efforts to disconnect the macroeconomy from volatile commodity markets.

1.13 There are also opportunities for new jobs. The UK has a strong base to build upon – latest official statistics show there are already over 410,000 jobs in low carbon businesses and their supply chains across the country with turnover estimated at £42.6 billion in 2019.[17] The Net Zero Review considered the labour market in its interim report (see Annex B). To ensure the UK has the skilled workforce to deliver net zero, the Green Jobs Taskforce was launched in November 2020. The independent Green Jobs Taskforce has concluded its work, with the publication of its recommendations to government, industry and the skills sector on 14 July 2021. Government has considered these recommendations as part of the development of the Net Zero Strategy, building on the work already underway to delivery the skills for net zero. Over the longer-term, the government has announced a cross-cutting delivery group to oversee the development and delivery of the government's plans for green jobs and skills.

## High levels of investment will be necessary, with the potential to boost the UK economy

### Investment need and potential impact

1.14 Decarbonising the UK economy will require investment in new equipment and processes to replace the existing fossil fuel-based capital stock. For example, companies will need to reduce their emissions directly, capture them through carbon capture and storage (CCS) or pay to offset their emissions through greenhouse gas removal technologies (GGRs). Households will need to switch to decarbonised heating sources, such as heat pumps, and to zero emission vehicles. This investment will be essential to drive the transition to net zero and its macroeconomic impacts – and similar decisions will be being made globally.

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14 'Energy innovation needs assessment: overview', BEIS & Vivid Economics, 2019.

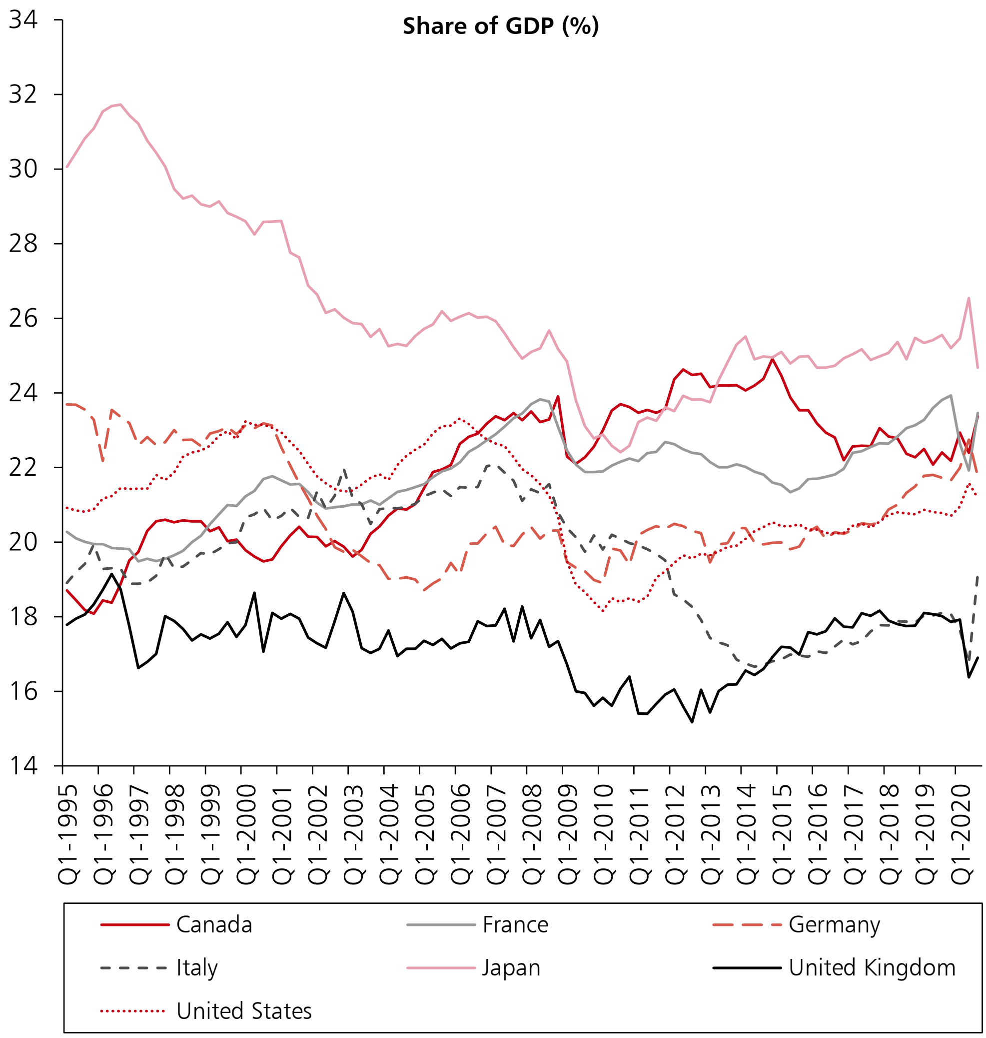
15 'Oil shocks and the UK economy: the changing nature of shocks and impact over time', Bank of England, 2013.

16 The UK is also a net importer of gas. 'Digest of UK Energy Statistics', BEIS, 2021.

17 'Low carbon and renewable energy economy (LCREE) survey direct and indirect estimates of employment, UK, 2014 to 2019', Office for National Statistics (ONS), 2021.

1.15 The UK currently has relatively low total (i.e. private plus public) investment levels compared to other G7 economies, as shown in Chart 1.A. Investment in the UK has averaged around 17% of GDP since 1995, the lowest of all G7 economies. Low levels of investment results in low growth of the productive capital stock, which implies lower potential output growth. It may have also contributed in part to the UK's relatively slow productivity growth.

## Chart 1.A: UK investment as a share of GDP in comparison to G7 economies




*Source: OECD Statistics*

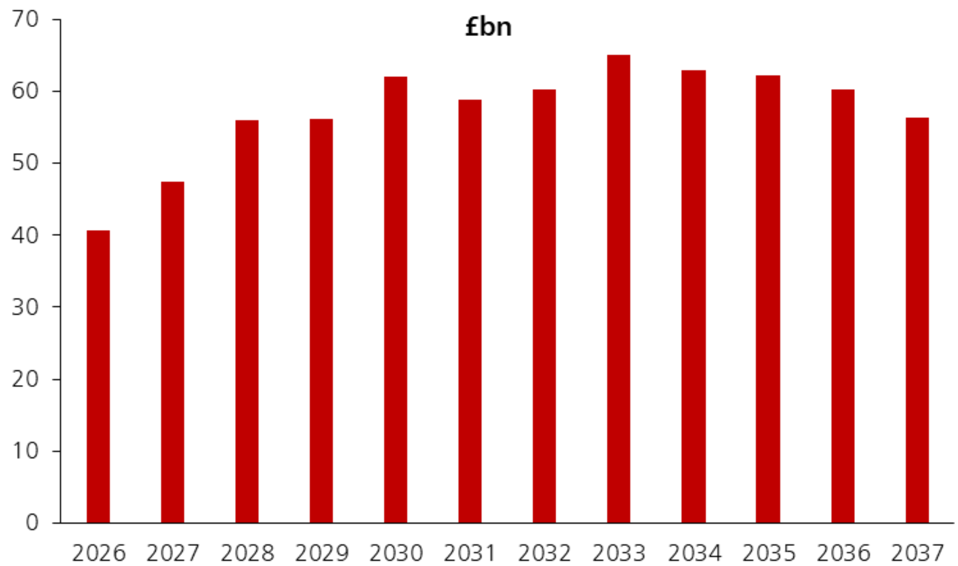
1.16 The investment required to decarbonise the UK economy could help to improve the UK's relatively low investment levels and increase productivity. GDP multipliers for green investments in renewables can be between 2.2 to 2.5 times larger than fossil fuel energy investment, depending on time horizons and specification.[18] This means that the investment required to reach net zero can potentially improve productivity in the UK economy and therefore long-term growth. However, some net zero technologies, such as Carbon Capture, Usage and Storage (CCUS), will impose additional costs on an ongoing basis. The overall productivity impact crucially depends on the degree

[18] 'Building Back Better: How Big Are Green Spending Multipliers?', Batini et al.,IMF Working Paper, 2021.

to which the new technologies require lower operating costs and increase output compared to existing technologies.[19]

1.17 Limiting global warming to 2°C, and pursuing efforts towards 1°.5C , above pre-industrial levels requires significant levels of investment across the economy. The exact size and profile of the investment required is uncertain, but most of it will come from the private sector. Chart 1.B shows the government estimate of the overall additional capital expenditure requirements for achieving net zero.[20] These estimates do not capture the entirety of net zero investment but estimate the additional investment required in order to achieve net zero; for example, the additional cost of investing in an electric vehicle over and above what it would cost to purchase a petrol or diesel vehicle, prior to reaching cost parity. This shows additional net zero investment peaking at over £60 billion by the mid-2030s. To contextualise this, in 2029 the additional net zero investment is almost 17% of the Office for Budget Responsibility's (OBR) Gross Fixed Capital Formation forecast.[21]

## Chart 1.B: Potential public and private additional capital expenditure requirements for achieving net zero[22]




*Source: Net Zero Strategy analysis*

1.18 The amount of investment required will be determined by a range of factors. These include changes in efficiency, falls in technology costs and the mix of technologies chosen. For example, natural gas heating may be replaced with hydrogen in the existing gas grid or by electrification. If hydrogen is produced from natural gas it requires relatively less investment but has higher ongoing

[19] 'World Economic Outlook, 2020: A Long and Difficult Ascent', IMF, 2020.

[20] Expenditure requirements set out in the Net Zero Strategy. This chart is illustrative and does not imply a specific pathway for government policy.

[21] 'March 2021 Economic and Fiscal Outlook', OBR, 2021.

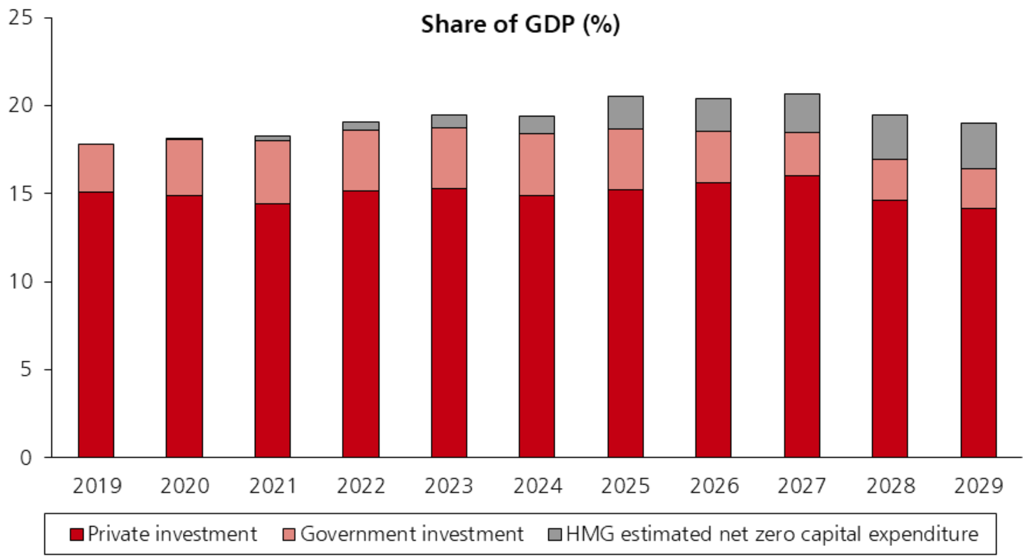
[22] Chart 1.B shows a scenario where heat is predominately decarbonised via electrification through heat pumps.

costs. The role of government and markets in keeping total costs down and ensuring an efficient transition is discussed in more detail in Chapter 5.

1.19 The extent to which this additional investment will translate into additional long-term GDP growth is uncertain. All other things being equal, additional investment will translate into additional GDP growth. However, more green investment is likely to attract diminishing returns,[23] reducing the positive impact of ever more investment on GDP. Some green investments could also displace other, more productive, investment opportunities. This risk may be accentuated later in the transition, if more productive investments are made earlier in the transition. To the extent that additional investment does not stimulate additional growth, this implies a structural rebalancing away from consumption.

1.20 Chart 1.C shows what the scale of this structural rebalancing could look like for the UK economy. Assuming that the net zero investment is additional, but with no multiplier for additional growth, the transition could increase the investment share of GDP by between 1% to 3% this decade. This rebalancing potentially has the added benefit that, when there is spare capacity in the economy, recoveries driven by investment empirically tend to be more sustained than those driven by consumer expenditure.[24]

## Chart 1.C: The OBR's Gross Fixed Capital Formation forecast and the government's estimated CAPEX requirements for achieving net zero, stylised as additional investment[25]




[23] 'Investing in Climate, Investing in Growth', OECD, 2017.

[24] 'Fiscal responsibility in advanced economies through investment for economic recovery from the COVID-19 pandemic', Stern and Zenghelis, 2021.

[25] The OBR March 2021 forecast provides GFCF forecasts up until 2029. The projections are based on fiscal announcements; at SR20 the government announced £100 billion of capital investment in 2021-22, a £30 billion cash increase compared to 2019-20, and £12 billion committed to the green revolution. The OBR's Gross Fixed Capital Formation (GFCF) forecast makes a distinction between government and private investment. Net Zero Strategy estimates for net zero capital expenditure is the additional net zero investment, with no distinction between government and private investment. The Net Zero Strategy capital investment profile is used here is the higher cost pathway.

*Source: OBR, Net Zero Strategy analysis*

1.21 The size of the effect on GDP will also vary by the type of investment and the wider economic and innovation environment. Effective government signalling, shifts in consumer demand towards greener products, rapid technological progress and aligning companies' investment horizons with the net zero trajectory can all maximise the efficiency and productive potential of private sector investments.[26] Existing public investment programmes in research and development (R&D) and infrastructure can act as effective enablers for this private investment.[27]

## Financing need

1.22 This large increase in investment across the UK economy to achieve net zero will require new financing flows. The mix of these new sources of finance could affect the financial conditions in the economy and the extent to which the investment stimulates growth.[28]

1.23 The cost of finance is currently low. However, interest rates can rise sharply and abruptly. The Bank of England's 2017 survey on the financial system and productive investment shows that the Weighted Average Cost of Capital, before tax, has fallen steadily since the financial crisis.[29] This reduces the cost of borrowing and provides more opportunity for green investment in the wider economy to take advantage of the low interest rates. However, the cost will rise if interest rates rise, all else being equal.

1.24 The low interest rate environment will change over time and is partly endogenous to drivers of savings and investment. An increase in green investment to take advantage of the current low interest rates may raise the economy's natural rate of interest if the increase in investment is sustained and not cyclical. Although this will make investment more expensive to finance, it should also reflect higher potential returns to new investment via higher productivity.

1.25 The financial services sector has an important role to play in the transition. Affordable finance is likely to be essential for households to spread the costs of higher capital investments. The sector will also play a pivotal role in reorienting financing flows to ensure that the transition happens in an orderly way and so limits the risks of unproductive investment. Box 1.A outlines the

26 'Macro-economic analysis of green growth policies: the role of finance and technical progress in Italian green growth', Paroussos et al., 2019; 'Socio-macroeconomic impacts of meeting new build and retrofit UK building energy targets to 2030: a MARCO-UK modelling study', Nieto et al., Sustainability Research Institute, 2020; 'World Economic Outlook', 2020: 'A Long and Difficult Ascent', IMF, 2020; 'Economic impact of the Sixth Carbon Budget', Cambridge Econometrics, Climate Change Committee (CCC), 2020; 'Investing in Climate, Investing in Growth', OECD, 2017.

27 'World Economic Outlook', IMF, 2014; 'Public Capital and Economic Growth: A Critical Survey, Romp & de Haan, 2007; 'The Intellectual Spoils of War? Defense R&D, Productivity and International Spillovers, and Moretti', Steinwender & Van Reenen, 2019; 'Economic Welfare and the Allocation of Resources for Invention', Arrow, 1962.

28 'Crowding-Out and Crowding-In Effects of the Components of Government Expenditure', Ahmed and Miller, 1999; 'Public Capital and Economic Growth: A Critical Survey', Romp & de Haan, 2007; 'Investing in Climate, Investing in Growth', OECD, 2017.

29 'The financial system and productive investment: new survey evidence', Bank of England, 2017.

steps government is taking to position the UK at the forefront of green finance. The financial services sector increasingly recognises the investment opportunities associated with the transition to net zero. In the UK in 2020, 25% of Assets Under Management were subject to criteria excluding investment in certain sectors or companies based on responsible investing principles, up from 18% a year earlier.[30]

### Box 1.A: Green finance

Mainstream private finance will be needed to support companies to realign their business models to achieve net zero. The Glasgow Financial Alliance for Net Zero (GFANZ) was launched to embed net zero across the financial system by expanding the types and number of financial institutions that are credibly committed to net zero, as well as implementing net zero commitments through technical workstreams. GFANZ currently represents nearly 300 financial institutions across 40 countries with total assets of more than US$90 trillion[31].

The government is also taking steps to position the UK at the forefront of green finance.

- The Green Finance Strategy sets out the government's approach to greening financial systems, mobilising finance for clean and resilient growth, and capturing the resulting opportunities for UK firms, while an objective of the UK's presidency of COP26 will be to ensure that climate change is factored into every financial decision. The government will update the Green Finance Strategy in 2022. This will set out an indicative sectoral transition pathway out to 2050 to align the financial system with the UK's net-zero commitments.
- The UK will implement a green taxonomy, which will define which economic activities make a significant contribution to net zero – enabling the finance sector and the corporations and consumers that use it to understand their impact on the environment. To achieve this, the UK has joined the International Platform on Sustainable Finance (IPSF). The UK has also established the Green Technical Advisory Group, which will provide independent, non-binding advice to the government on developing and implementing the UK taxonomy.

  The clear and transparent disclosure of climate change risk and the impacts of economic activities on the environment can help financial institutions, policy makers and consumers to consider these factors in their decision-making. The UK government supports the Task Force on Climate-related Financial Disclosures (TCFD), which published recommendations forming a framework for disclosing the financial risks and opportunities posed by climate change. In November 2020, the government announced its intention to make TCFD-aligned disclosures mandatory in the UK across the economy by 2025, with a

30 'Investment Management in the UK 2020-2021', The Investment Association Annual Survey, 2021.

31 'Call to Action', Glasgow Financial Alliance for Net Zero, 2021.

significant portion of mandatory requirements in place by 2023. In July 2021 the Chancellor announced government plans to introduce economy-wide Sustainability Disclosure Requirements for businesses and financial products to disclose their impact on climate and the environment as well as the risks and opportunities these pose to their business; this builds on and streamlines existing sustainability reporting requirements such as our commitment to economy-wide TCFD reporting. On 18 October 2021, the government published a Roadmap setting out further detail on its approach to implementing the Sustainability Disclosure Requirements. The Chancellor also announced that the government will work with the Financial Conduct Authority (FCA) to create a new sustainable investment label – a quality stamp – so that consumers can clearly compare the impacts and sustainability of their investments for the first time.

- As announced at March Budget 2021, Dame Clara Furse has established a new group with the aim of positioning the UK and the City of London as the leading global market for high quality voluntary carbon offsets, which can play an important role in addition to international efforts to reduce carbon emissions. The working group will draw on the UK's financial expertise and entrepreneurship and build on the work of crossing-cutting initiatives such as the Taskforce for Scaling Voluntary Carbon Markets.

## Co-benefits

1.26 Air quality improvements from reduced emissions from pollutants, in particular through the reduced combustion of fossil fuels, will have both health and economic benefits. The UK has made huge progress in reducing emissions of all five major air pollutants, and on the whole, air quality has improved significantly in recent decades – since 2010, emissions of nitrogen oxides have fallen by 32% and are at their lowest level since records began.[32] The government has also put in place a £3.8 billion plan to improve air quality and transport.[33] This includes supporting uptake of ultra-low emissions vehicles, cycling and walking and helping local authorities develop and implement local air quality plans, as well as supporting those impacted by these plans. Impacts will vary between air pollutants. Box 1.B provides further details on nitrogen oxides impact on air quality.

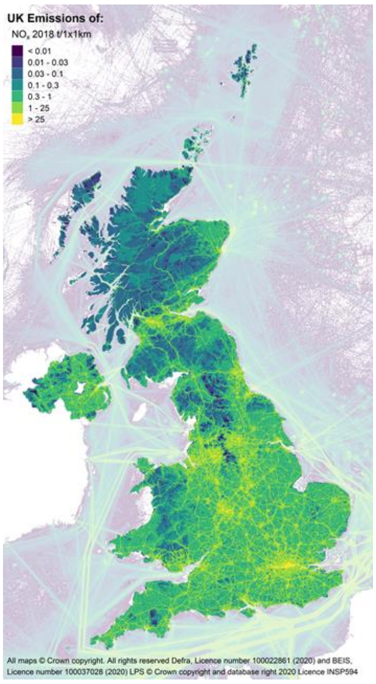
[32] 'Emission of air pollutants in the UK – nitrogen oxides (NOx)', DEFRA, 2021.

[33] 'Air quality factsheet (part 4)', DEFRA, 2021.

## Box 1. B: Air Quality and nitrogen oxides

Nitrogen oxides (NOx) are a group of polluting gases that are mainly formed during the combustion of fossil fuels. Currently, the road transport sector emits 33% of nitrogen oxide (NOx) emissions, which are concentrated in towns and cities.[34] Short-term exposure to concentrations of NOx can cause inflammation of the airways and increase susceptibility to allergens. NOx can also exacerbate the symptoms of those already suffering from lung or heart conditions and aggravating respiratory diseases.[35] This impacts public health across the population but may have a disproportionate impact on some demographics, including those living in the most deprived areas in the UK.

### Image 1.A: UK emissions from NOx in 2018




*Source: National Atmospheric Emissions Inventory*

1.27 Decarbonisation will have a further positive impact on this persistent public health challenge. BEIS modelling indicates that, at a national level, air quality pollutant emissions will be lower as a result of the transition. This could deliver £35 billion worth of economic benefits in the form of reduced damage costs to society, reflecting for example lower respiratory hospital admissions.[36] Where these benefits allow for a healthier and more productive workforce, they can support long-term growth and productivity improvements.

1.28 Another benefit from the transition is improvement in agricultural soil and peatland restoration through changed agricultural practices and land use. This will positively impact water quality by reducing nutrient leaching and

34 'Emissions of air pollutants in the UK – Nitrogen oxides (NOx)', DEFRA, 2021.

35 'Statement on the evidence for the effects of nitrogen dioxide on health', Committee on the Medical Effects of Air Pollutants, 2015.

36 'Impact Assessment for the Sixth Carbon Budget', BEIS, 2021.

sedimentation through reduced soil erosion. BEIS analysis estimates this will deliver £3.1 billion of economic benefits over the transition. This reflects the value of improving water quality in rivers, lakes, canals and coastal waters which impacts biodiversity, amenity and recreation.[37]

1.29 The transition to net zero is likely to generate positive co-benefits in terms of habitat restoration, connectivity, resilience and reducing ecological stress caused by climate change. Conversely, the introduction of certain new low carbon technologies, marine policies, land management and agricultural intensification may in some cases lead to negative impacts including displacement, noise pollution and loss of habitat. However, overall BEIS estimates a net positive impact of £0.5 billion of economic benefits from biodiversity across the transition.[38]

1.30 Domestic and international efforts can help drive a reduction in global emissions, which can help reduce the incidence of flood risk, such as coastal erosion, in the UK. In 2015-16 the economic cost to the economy from flooding was £1.6 billion in the form of damage to homes and businesses. The cost in 2019-20 was £78 million but would have cost an extra £2.1 billion without flood defences. Additionally, the BEIS Sixth Carbon Budget impact assessment estimates a net economic benefit of £0.8 billion across the transition derived from flood management and environmental landscape.

37 'Impact assessment for the sixth carbon budget'. BEIS, 2021.

38 'Impact assessment for the sixth carbon budget'. BEIS, 2021.

# Chapter 2

# Net Zero and international competitiveness

The shift to a global low carbon economy presents new opportunities for the UK to be a leader in specific areas of the green economy. The main opportunities are likely to be where the UK can build on established strengths, such as in services where the UK can continue to be a global leader. Integration in global value chains means the UK will also benefit from green innovation and production in other countries.

However, this shift will involve significant structural change in the UK economy which will affect sectors in different ways depending on the cost of abatement and their exposure to international trade. There is a risk that some business activity might move jurisdiction because of less stringent climate change mitigation policies elsewhere. This would undermine the environmental objectives of domestic mitigation in the sectors affected.

Evidence of carbon leakage to date is inconclusive, but as the UK adopts more ambitious initiatives to reduce its emissions, the risk of carbon leakage should be taken into account. This chapter sets out some analysis of Organisation for Economic Co-operation and Development (OECD) data on the carbon intensity of different sectors in the UK and globally, and its implications. There are various policy options open to government as it seeks to manage the risk of future carbon leakage, but each come with their own advantages and limitations.

## Overview

2.1 The UK is an open, trading economy. This affects how the UK can best decarbonise and maintain competitiveness. In identifying opportunities from decarbonisation, the UK will need to consider where it is most competitive compared to other economies.

2.2 Different countries decarbonising at different paces creates a risk of carbon leakage. Policy needs to take this into account to ensure efforts to reduce UK emissions are also effective at reducing global emissions.

# The UK's comparative advantage in a low carbon global economy

## Policy that focuses on comparative advantage can support green economic growth across the UK

2.3 Policy that supports efficient resource and capital allocation into areas of UK comparative advantage can improve UK competitiveness and exports in the shorter term and contribute to UK productivity growth in the longer term.

2.4 The approach to comparative advantage in the transition to net zero aligns with wider economic objectives to contribute to increased long-term growth across the UK. The UK's most competitive green industries will require investment and innovation outside of the UK's existing services and research hubs but a focus on comparative advantage will still be beneficial. Successful levelling up will require local growth and the UK's most competitive green industries could build on existing regional strengths to contribute to sustainable growth across the country.

2.5 A range of policy levers can be employed to encourage firms to invest and innovate in areas of UK comparative advantage in the transition. Clear signals from government on carbon pricing, regulatory standards, infrastructure deployment and public-private risk-sharing can support private investment and innovation.

## Current UK comparative advantage is the basis of probable comparative advantage in the green economy

2.6 The UK has a comparative advantage in a product or activity if it can produce it at a lower opportunity cost than its competitors. The principle implies that the UK should focus on production of those high-value goods, services and innovative activities where it is most competitive. It can then trade these for other goods and services where other countries have a comparative advantage over the UK. Consumers and producers in the UK and trading partners enjoy the efficiency gains from each country specialising and trading.

2.7 UK comparative advantage is primarily dependent on the unique combination of economic fundamentals that other countries cannot easily replicate: a highly educated, English-speaking workforce; world-leading research universities; and an extensive coastline with a shallow seabed, among many other strengths.

2.8 In the transition to net zero many of the UK's current strengths will adapt, and can be built on, to meet growing green demand domestically as well as for exports. This is likely to be a gradual evolution rather than a sudden shift. For example, UK expertise in offshore platform installation and management from the oil and gas industries will increasingly apply instead to the offshore wind sector.[1] Clear policy signals and commitments can help to realise the new opportunity in some areas.

[1] 'Energy innovation needs assessment: offshore wind', BEIS & Vivid Economics, 2019.

2.9 The durability of UK economic fundamentals and the high potential for adaptation of existing activities suggests that areas of probable comparative advantage in the green economy are likely to be based on existing areas of UK comparative advantage. This means that it should be easier to become competitive in areas using "similar production capabilities and know-how" to current UK strengths.[2]

2.10 Future UK comparative advantage is likely to continue to be highly focused. Emerging green sectors will have complex supply chains, encompassing probable UK strengths and weaknesses. As in the current economy, the UK will not be competitive in every value chain stage of individual sectors but should be competitive in at least some stages of multiple sectors.[3] Policy that supports specific UK strengths with a broad application across green sectors is more likely to contribute to economic opportunities than spreading resources across every part of one supply chain. Policy should be designed to account for challenges and opportunities in the value chains of individual green sectors.

2.11 The UK has deep strengths in specific areas of advanced manufacturing that will be at the heart of the green industrial revolution, as outlined in the Ten Point Plan for a Green Industrial Revolution.[4] The Plan for Growth further highlights the UK's world-leading position in scientific research, which could support adoption and diffusion of many innovative green technologies.[5]

2.12 The UK also currently has a very strong comparative advantage across a broad range of professional, financial, and engineering and design services. In 2020, the UK had a trade in services surplus of £107.4 billion; in 2019 the UK was the world's second-largest exporter of services.[6] The UK has a 'natural advantage' in providing services for a low carbon economy, including financing, legal and consulting expertise and software services.[7]

## Building on current UK comparative advantage can enhance transition opportunities and reduce costs

2.13 Embedding comparative advantage among other decarbonisation policy objectives can benefit UK firms. Building on existing UK strengths could open new opportunities in the transition, increase UK exports and help secure a competitive UK green economy for the long term.

2.14 A focus on UK comparative advantage can also benefit households. Building on UK strengths while taking advantage of other countries' strengths would improve the quality, price and range of goods and services available to consumers. UK comparative advantage is partly determined by the skills of the

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2 'Rebuilding to last: how to design an inclusive, resilient and sustainable growth strategy after Covid-19', Rydge & Zenghelis, 2020.

3 'Energy innovation needs assessment: offshore wind', BEIS & Vivid Economics, 2019.

4 'The Ten Point Plan for a green industrial revolution', HM Government, 2020.

5 'Build back better: our plan for growth', HM Treasury, 2021.

6 'Trade and investment core statistics book', Department for International Trade (DIT), 2021. 2019 ranking is based on the latest available UNCTAD data, much of which are modelled/estimated.

7 'UK export opportunities in the low-carbon economy', Carvalho & Fankhauser, 2017.

UK labour market; an increased focus on UK strengths by competitive firms may increase demand for UK workers and their skills.

2.15 Finally, designing policy to encourage private investment into areas of known comparative advantage should reduce the risk of government making uncompetitive or sub-optimal choices at taxpayers' expense. Private firms hold the commercial expertise that make them better placed to make complex judgements on how to adapt to new consumer demand or competitor threats.

## First movers can draw an advantage by setting global direction, but only if they are already established leaders

2.16 The UK must act before some other countries in order to meet legally binding decarbonisation requirements. Competitive and innovative UK firms may be able to turn their early expertise into increased future exports. In general, UK strengths rely on complex innovation, skills and technology, rather than low labour or resource costs. The UK is more likely to increase global market share by acting decisively by acting early and decisively in areas of comparative advantage, innovating continually, and encouraging the adoption of global low carbon standards.

## Policy can respond to new risks and opportunities for UK comparative advantage in the transition

2.17 The UK is not alone in aiming to decarbonise its economy – the majority of global GDP is now covered by net zero targets.[8] Competitors will improve existing technologies or innovate for new high-growth, low carbon production. Competitive UK firms will need to respond to global action to capitalise on new export opportunities.

2.18 Policy could support UK industries to transition into "technologically proximate green products" – goods similar to existing UK strengths in which the UK could potentially become competitive.[9] It could encourage low carbon innovation as a way to maintain or gain areas of UK competitiveness in the transition.[10] Policy should create an environment that encourages concentrated innovation by firms, rather than only set targets for specific technologies.

2.19 Policy must also encourage the necessary infrastructure, skills and business environment for current and future UK comparative advantage to flourish, including in the services economy.

8 'Taking stock: a global assessment of net zero targets', The Energy & Climate Intelligence Unit (ECIU) and Oxford Net Zero, 2021.

9 'Economic complexity and the green economy', Mealy & Teytelboym, 2018.

10 'The readiness of industry for a transformative recovery from Covid 19', Fankhauser, Kotsch & Srivastav, 2020.

# Trading partners decarbonising at different speeds can give rise to carbon leakage risks

## Defining carbon leakage

2.20 Climate rules and policies designed to reduce emissions in a given country can increase the costs of production of its businesses (including indirectly because of the impact on the price of inputs, such as energy) relative to international competitors if those competitors are subject to weaker climate change mitigation policies.

2.21 If such rules and policies (such as carbon pricing, or other emissions reduction policies), are not implemented in an equivalent way across jurisdictions, this can result in production and the associated greenhouse gas (GHG) emissions being displaced, undermining the original environmental objective of climate mitigation policies - this displacement of GHG emissions is known as carbon leakage. In general, carbon leakage can be said to occur if all of the following conditions are satisfied:

- Climate mitigation policies differ across jurisdictions;
- Emissions shift to a region with lower climate mitigation obligations; and,
- Shifts in production to a firm in a different jurisdiction lead to a sustained increase in emissions intensity, higher than it would have been had production not moved.

2.22 There are three main channels by which carbon leakage can occur:

- Businesses in the jurisdiction with more ambitious emission reduction policies face higher costs, causing a drop in domestic output, and an expansion elsewhere;
- Differences in the strength of emission reduction policies could influence investment decisions, causing a shift in future production to other jurisdictions; and,
- A reduction in demand for fossil fuels due to mitigation policies in some countries could reduce international fossil fuel prices relative to where they would otherwise have been. This could incentivise businesses in other countries to increase fossil fuel consumption.

2.23 While it can provide a conduit for carbon leakage, trade also plays a vital and positive economic role. Trade is central to developing and sustaining livelihoods in the UK and across the world, including in developing countries, encouraging production where it is most efficient, and giving consumers more choice and lower prices. Agricultural trade, for example, is particularly important for channelling food from areas of surplus supply to food-deficit countries. These food security benefits of trade are likely to grow as climate change generates increasingly frequent and significant supply shocks.

2.24 Although carbon leakage manifests itself at the national level, and action to address it can be taken at a national level, at its heart, carbon leakage is caused by different approaches across jurisdictions to the mitigation of emissions. As such, the first best solution is effective international co-operation and policy co-ordination. Failing that, other options would need to be considered.

## A range of factors affects a sector's exposure to carbon leakage risks

2.25 The literature on carbon leakage presents a mixed picture. Literature on the evidence of carbon leakage is commonly divided between empirical studies (ex-post) and theoretical literature/estimates (ex-ante).[11] Papers based on ex-ante modelling tend to support the suggestion that differential carbon pricing between trading partners can create material carbon leakage risks.[12] By contrast, ex-post studies have generally found limited evidence of carbon leakage to date. For example, studies looking at the first years of the EU Emissions Trading Scheme (EU ETS) find limited to no evidence of leakage.[13]

2.26 A range of factors affects a sector's exposure to carbon leakage risks.[14] However, there are some indicators that can allow us to identify those sectors where the risk of carbon leakage is higher. If a sector has a relatively low level of carbon intensity per $million of production, then even a relatively high carbon price will not have a significant impact on costs, suggesting the risk of carbon leakage is likely to be relatively low. Conversely, a relatively high level of carbon intensity would suggest a more significant risk of carbon leakage, unless, for example, abatement costs are low, trade openness is low, and/or profitability is relatively strong. Looking ahead, if a sector undergoes a quicker process of decarbonisation compared to that of key trading partners, then this could increase the risk of carbon leakage.

2.27 It is possible to draw on the OECD's Trade in Embodied $CO_2$ database ($TECO_2$) to consider the potential for carbon leakage risks based on absolute and relative levels of carbon intensity by sector. The $TECO_2$ provides estimates of embodied emissions across countries and by sector. It offers interesting insights, but it also has important limitations. For example, there is a relatively high degree of sectoral aggregation which can inadvertently mask the situation in specific industries. Furthermore, the dataset focuses on $CO_2$ emissions from fuel combustion, and does not therefore take account of other greenhouse gases like methane or nitrous oxide, or emissions from chemical reactions that are part of the production process. All of the caveats taken together mean that the results should be regarded as indicative orders of magnitude, rather than precise estimates. Indeed, for some individual industries, the numbers presented below could be under-

[11] 'Climate Policy Leadership in an Interconnected World: What Role for Border Carbon Adjustments?', OECD, 2020.

[12] 'Would border carbon adjustments prevent carbon leakage and heavy industry competitiveness losses? Insights from a meta-analysis of recent economic studies.', Branger and Quirion, 2014.

[13] At least in part, this is due to historically low carbon prices compared with what is needed to reach Net Zero, and the impact of measures such as free allowances under the ETS.

[14] Examples include relative carbon intensities and carbon pricing, the scope for a sector to adjust in the face of cost pressures, prevailing marginal abatement costs, available technologies, and the degree of trade openness in a sector.

estimates. More information on the TECO2 database, and the relevant caveats, are set out in Annex A.

## Table 2.A: $CO_2$ intensity for manufacturing sectors

| | CO2 intensity embodied in exports (tonne/$ million, 2015)[15] | | | Relative CO2 intensity (UK=100) | |
|---|---|---|---|---|---|
| Sector | UK | OECD | Non-OECD | OECD | Non-OECD |
| Basic metals | 990 | 1,104 | 2,283 | 112 | 231 |
| Chemicals & pharmaceuticals | 206 | 374 | 977 | 181 | 473 |
| Computers & electronics | 175 | 261 | 606 | 149 | 346 |
| Electrical equipment | 251 | 366 | 1,049 | 146 | 417 |
| Fabricated metals | 230 | 402 | 1,344 | 175 | 584 |
| Machinery and equipment | 258 | 301 | 1,058 | 117 | 410 |
| Mining & energy extraction | 425 | 590 | 487 | 139 | 115 |
| Mining of non-energy products | 241 | 484 | 605 | 201 | 251 |
| Motor vehicles | 224 | 266 | 801 | 119 | 358 |
| Non-metallic minerals | 514 | 835 | 2,291 | 162 | 445 |
| Other manufacturing | 245 | 312 | 1,306 | 127 | 532 |
| Other transport equipment | 206 | 270 | 690 | 131 | 336 |
| Paper | 238 | 419 | 804 | 176 | 337 |
| Refineries | 821 | 693 | 1,011 | 84 | 123 |
| Rubber and plastics | 394 | 368 | 1,394 | 94 | 354 |
| Textiles and apparel | 198 | 265 | 571 | 134 | 289 |
| Wood products | 223 | 330 | 607 | 148 | 272 |

*Source: OECD, HM Treasury calculations*

2.28 Carbon intensity data are presented in Table 2.A and include total $CO_2$ embodied directly (from fuel consumed in the production process) and indirectly (from domestic and foreign inputs). The left-hand side of the table presents, in absolute terms, figures for the quantity of carbon per $million of exports in the UK compared to averages for the OECD and non-OECD countries respectively.

2.29 For many sectors, UK emission intensity figures are lower than the OECD average, although the OECD averages conceal a range of country-by-country numbers, some of which will be lower than the UK's figures. For any given sector there could be several factors driving this difference, such as the use of different technologies and different energy mixes underlying electricity production. However, the UK's power sector's relatively low $CO_2$ emissions compared to the OECD is likely to be a key factor.[16] The gaps between the UK and non-OECD average figures are starker, although once again the average figures conceal a range of intensities.

2.30 Although Table 2.A suggests that there are some significant gaps in carbon intensity between the UK and other countries (suggesting scope for carbon

[15] CO2 emissions embodied in exports should also be a good reflection of the CO2 emissions embedded in gross output.

[16] 'The UK's contribution to a Paris-consistent global emissions reduction pathway. Report to the UK Committee on Climate Change. Grantham Institute, Imperial College London.', Gambhir, A., Grant, N., Koberle, A. and Napp, T., 2019.

leakage), Table 2.B shows that illustrative estimates of the impacts on costs,[17] when UK carbon intensity are combined with different levels of carbon pricing, appear to be relatively modest for most sectors. This approach applies a single carbon price per tonne of $CO_2$ to illustrate the impact of various carbon pricing levels. However, in practice, in the UK, a combination of implicit and explicit carbon prices are applied in some sectors, reinforcing the point that these estimates are notional and illustrative. The two sectors most affected in this analysis are basic metals and refining, both of which also have relatively high levels of trade openness. Next comes non-metallic minerals where trade openness is less marked.[18]

## Table 2.B: Carbon intensity for UK manufacturing sectors, and the illustrative cost of carbon pricing

| Sector | Overall trade openness[19] | UK-sourced carbon intensity[20] ($CO_2$ tonne/ $ million) | Proportion of $CO_2$ from domestic sources | Illustrative cost of UK carbon pricing (% of gross output) | | |
|---|---|---|---|---|---|---|
| | | | | $50/tonne | $75/tonne | $100/tonne |
| Computers & electronics | 78% | 71 | 41% | 0.4% | 0.5% | 0.7% |
| Textiles and apparel | 76% | 125 | 63% | 0.6% | 0.9% | 1.2% |
| Mining & energy extraction | 75% | 381 | 90% | 1.9% | 2.9% | 3.8% |
| Basic metals | 72% | 790 | 80% | 3.9% | 5.9% | 7.9% |
| Other transport equipment | 72% | 76 | 37% | 0.4% | 0.6% | 0.8% |
| Chemicals & pharmaceuticals | 70% | 121 | 59% | 0.6% | 0.9% | 1.2% |
| Motor vehicles | 69% | 96 | 43% | 0.5% | 0.7% | 1.0% |
| Electrical equipment | 69% | 90 | 36% | 0.4% | 0.7% | 0.9% |
| Machinery and equipment | 67% | 118 | 46% | 0.6% | 0.9% | 1.2% |
| Other manufacturing | 54% | 170 | 69% | 0.8% | 1.3% | 1.7% |
| Refineries | 52% | 681 | 83% | 3.4% | 5.1% | 6.8% |
| Rubber and plastics | 51% | 300 | 76% | 1.5% | 2.3% | 3.0% |
| Wood products | 35% | 122 | 55% | 0.6% | 0.9% | 1.2% |
| Fabricated metals | 34% | 112 | 49% | 0.6% | 0.8% | 1.1% |
| Mining of non-energy products | 32% | 176 | 73% | 0.9% | 1.3% | 1.8% |

17 Based on ad-valorem impacts.

18 These intensity figures do not capture CO2 emitted from the chemical reactions involved in the production of cement.

19 Overall trade openness is calculated as (UK imports + UK exports) over total UK supply.

20 These calculations use domestic carbon emissions embodied within UK exports to calculate illustrative ad-valorem costs, which implicitly assume UK production intensity is equivalent to export intensity and all domestically sourced carbon is priced (incl. electricity, transport inputs etc). Costs are calculated as domestically sourced carbon intensity multiplied by carbon price per tonne.

| | | | | | | |
|---|---|---|---|---|---|---|
| Non-metallic minerals | 30% | 417 | 81% | 2.1% | 3.1% | 4.2% |
| Paper | 28% | 157 | 66% | 0.8% | 1.2% | 1.6% |

*Source: OECD, HM Treasury calculations*

2.31 Trade patterns matter in any assessment of carbon leakage risk. Import competition from countries with higher carbon intensities and lower carbon prices are often the focus of discussions around carbon leakage, but it is equally important to consider the implications for UK exports. Aside from competition in the domestic market from imports, UK exporters paying a carbon price in the UK have to compete overseas with products (whether produced in the destination market, or in third countries also exporting to that market) that may not have paid a comparable or higher carbon price. Given the high levels of exports as a proportion of production in some sectors (see Table 2.C) this could be a material issue when considering the competitiveness of UK exporters. For example, UK exports of basic metals and chemicals account for more than 50% of domestic production in those sectors.

## Table 2.C: Trade openness of UK manufacturing sectors

| Sector | Share of total UK GVA (%) | Trade openness measures | | |
|---|---|---|---|---|
| | | Imports proportion of demand (%) | Exports proportion of production (%) | Overall trade openness (%)[21] |
| Basic metals | 0.3 | 54 | 59 | 72 |
| Chemicals & pharmaceuticals | 1.5 | 54 | 53 | 70 |
| Computers & electronics | 0.5 | 72 | 49 | 78 |
| Electrical equipment | 0.3 | 61 | 40 | 69 |
| Fabricated metals | 1.0 | 24 | 18 | 34 |
| Machinery and equipment | 0.6 | 51 | 50 | 67 |
| Mining & energy extraction | 0.9 | 63 | 55 | 75 |
| Mining of non-energy products | 0.2 | 26 | 10 | 32 |
| Motor vehicles | 0.9 | 58 | 47 | 69 |
| Non-metallic minerals | 0.3 | 23 | 12 | 30 |
| Other manufacturing | 1.0 | 42 | 31 | 54 |
| Other transport equipm ent | 0.7 | 56 | 56 | 72 |
| Paper | 0.6 | 20 | 12 | 28 |
| Refineries | 0.3 | 45 | 21 | 52 |
| Rubber and plastics | 0.5 | 38 | 29 | 51 |
| Textiles and apparel | 0.4 | 73 | 33 | 76 |
| Wood products | 0.1 | 31 | 7 | 35 |

*Source: OECD, HM Treasury calculations*

[21] Overall trade openness is calculated as (UK imports + UK exports) over total UK supply.

2.32 In summary, this analysis suggests that some UK manufacturing sectors have substantially lower emissions intensities compared to some trading partners. Many of these sectors are also relatively open from a trade perspective. However, when different levels of carbon price are applied to sectoral emissions intensities, the impacts look relatively low for most sectors. The main exceptions are basic metals, refineries and non-metallic minerals.

2.33 The evidence for the risk of carbon leakage in the manufacturing sector is mixed, based on the OECD's Trade in Embodied $CO_2$ database. While there are likely to be material risks of carbon leakage, these will be sector specific, and the risks will be a function of variables (trade openness, relative carbon intensity, the cost of abatement and what key trading partners do on carbon pricing) that will change over time as technological developments affect the costs of abatement, and as efforts increase among trading partners to mitigate carbon emissions. More work is needed to build the evidence base and come to a more certain view of the issue across the different sectors.

## Agriculture

2.34 As with many other sectors, agriculture is associated with $CO_2$ emissions arising from the direct use of energy (for example the use of farm machinery). But unlike other sectors, the most important agricultural emissions are methane (for example generated by cattle and sheep) and nitrous oxide (for example arising from fertiliser applications). Another important factor that represents an even higher source of emissions in some countries is land-use change, especially deforestation. The Intergovernmental Panel on Climate Change (IPCC)[22] estimates that agriculture is directly responsible for up to 8.5% of all greenhouse gas emissions globally, with a further 14.5% due to land use changes, which are mostly linked to agriculture, and which also drive other negative environmental impacts such as biodiversity loss.

2.35 The OECD $TECO_2$ data do not take account of greenhouse gases beyond $CO_2$, or emissions associated with land use change. Chart 2.A, drawn from the Climate Change Committee (2020), is based on lifecycle analyses that take account of carbon dioxide, methane and nitrous oxide emissions as well as emissions from intermediate consumption, such as feed and fertilisers, and the emissions from land use change.[23] Taking the example of beef, it demonstrates that the levels of carbon intensity for agricultural products can differ substantially by country and production process.[24][25]

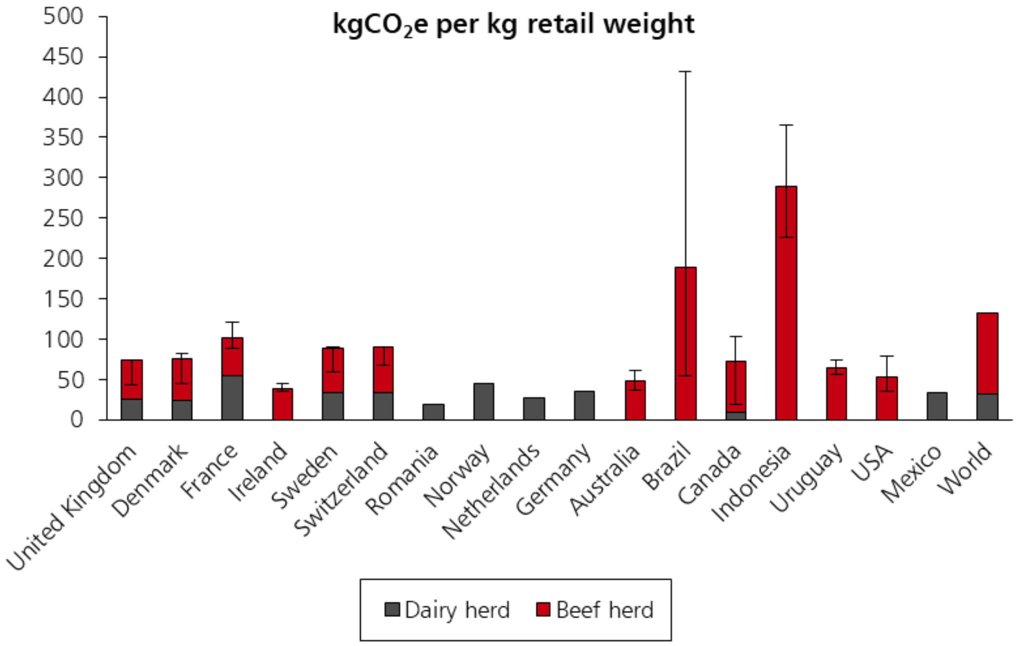
22 'Climate Change and Land – Special Report', Intergovernmental Panel on Climate Change, 2019.

23 The measurement of emissions from land use change associated with the production of specific products is complex, and estimates from different sources vary. More generally, there are also data gaps, so there is a risk of underestimation of emission intensities for some countries.

24 Differences between countries, and differences between livestock products are also presented by the OECD. 'Making Better Policies for Food Systems', OECD, 2021.

25 Biodiversity impacts can also differ substantially, and can be affected by agricultural trade. See for example, The Economics of Biodiversity: The Dasgupta Review, 2021.

## Chart 2.A: Lifecycle assessment of the greenhouse gas-intensity of beef production




*Source: CCC, drawing on Poore, J. & Nemecek, T.*[26]

2.36 The UK is a substantial net-importer of food. With UK Most Favoured Nation (MFN) agricultural tariffs set at relatively high levels, especially for livestock products,[27] the pattern of trade (and hence the carbon intensity of imports) is affected by the nature of preferential trade arrangements. The UK's main agricultural trading partner is the EU. This means that the risk of carbon leakage will depend to a significant extent on the relative level of ambition of emission mitigation policies in the UK and the EU, and the carbon intensity of EU agricultural production.

2.37 Aside from relative carbon intensities and trade patterns, and abatement costs, the scope for agricultural carbon leakage is affected by a range of factors, including the following:

- **Domestic price formation.** With the UK being a net importer of most agricultural products, domestic farm-gate prices for most goods will be a function of import parity.[28] So, UK farmers have limited scope to pass on emission mitigation costs to consumers;
- **Agricultural adjustment** will tend to mitigate the risk of carbon leakage. For example, if government sought to incentivise emission

[26] 'Reducing food's environmental impacts through producers and consumers', Science, 360 (6392), 987-992, Poore, J. & Nemecek, T., 2018.

[27] For example, the UK's ad valorem equivalent (AVE) MFN tariffs for beef is 79%. Sheep meat (54%), white sugar (70%), and butter and cheese (both 35%) are also significant. These tariffs include a specific tariff per unit of weight/volume, so the equivalent percentage tariff can be very variable. Percentage equivalents depend on the product, international price and exchange rate movements. Tariff rates in this footnote are calculated point estimates based 2017-19 average UK-EU trade as reported in HMRC Overseas Trade Data, and are therefore illustrative.

[28] The cost of landing imported product in the UK from the most competitive available origin.

mitigations in a way that increases production costs for farmers, there would be adjustments through the land market, and other adjustments by farmers, which would help to moderate any initial impacts on output and profitability;[29]

- **Substitution effects**. Because of the degree of substitution in production that is possible (and the scope for putting land to alternative uses), it is hard to assess carbon leakage by looking at individual products.[30] Instead, impacts need to be viewed in the round, which would involve assessing how far increases in the production of some products compensates, in carbon leakage terms, for output reductions for other products; and,

- **The scope to improve productivity**. The evidence suggests there is significant scope for the domestic agricultural sector to improve its productivity.[31]

2.38 As with manufacturing (but for different reasons), the evidence on the risks of carbon leakage is mixed. Some factors suggest that carbon leakage risks are significant:

- the gaps, for some products, between carbon intensity in the UK and other countries;

- the limited scope for farmers to pass on additional costs through higher prices; and,

- emission impacts of land use change due to expanded production in some countries.

2.39 Other factors point in the opposite direction:

- the capacity for the agricultural sector to adjust in the face of changing circumstances; and,

- the scope for the domestic agricultural sector to improve its productivity.

## Governments have options to influence carbon leakage

2.40 Although there are many uncertainties, and the data is imperfect, the analysis above suggests that some UK sectors are at risk of carbon leakage, and that these risks are likely to grow over time as government does more to mitigate

[29] This could be a switch in technology or input usage (for example, if particular inputs associated with emissions are targeted by policy) or a switch in patterns of production (perhaps through the increased use of legumes in arable rotations).

[30] If another product is less GHG intensive in its production and only marginally less profitable under the status quo, a quick shift from one product to another may be expected. Equally, for other products, costs may need to increase substantially before an impact is felt, if there is not another viable alternative without a substantial adjustment in costs.

[31] An example is the wide spread of performance across the domestic agricultural sector between the top and bottom quartiles. 'Future Farming and Environment Evidence Compendium', DEFRA, 2019.

emissions domestically. The government understands the concerns this generates in some sectors, and will need to take steps to tackle the issue.

## International action

2.41 Carbon leakage is not just a UK problem. Any country that is ambitious in tackling climate change will likely face domestic resistance to early and ambitious carbon pricing, because different levels of mitigation effort among trading partners can cause concerns about carbon leakage. These concerns generally manifest themselves at the sectoral level, and risk acting as a drag on mitigation effort at both the national and global levels.

2.42 As with all global challenges, the best solution is international action, and that can take many forms. The OECD finds that a global emissions price would be the most effective way to reduce leakage.[32] However, over three quarters of global emissions remain unpriced,[33] and even the most ambitious countries will not necessarily choose to rely on explicit carbon pricing, perhaps favouring other types of policy measures such as regulation. While that is the right of a sovereign government, it makes it harder to assess whether and how far national-level carbon pricing in any given sector results in a material carbon leakage risk. It is therefore imperative that government finds an international approach to comparing levels of effort, by sector, and across jurisdictions. Similarly, government need better ways to measure embodied emissions, which points to improved global carbon emissions data.

2.43 The UK's G7 Presidency has been a good opportunity to exchange views with its partners on the benefits and different methods of carbon pricing. The government has sought to build not just a common understanding of the carbon leakage risks, but also to develop the tools and insights that will be needed to tackle it collectively.

2.44 During 2021, there have been a number of specific proposals for co-ordinated action (see Box 2.A) which merit further consideration. The UK is also actively involved in similar discussions in the G20, and at the World Trade Organisation which offers a range of platforms to drive forward the climate agenda, including through the Trade, Environment and Sustainability Structured Discussions (TESS-D) grouping, and the Committee on Trade and Environment.

2.45 These broader international discussions are extremely important as any multilateral effort on carbon pricing and leakage needs to be as inclusive as it can be, working for the broadest range of countries. For example, any such initiatives will need to consider our obligations to the least developed countries (LDCs) under the Paris Agreement, and factor in potential compliance challenges that could arise from data intensive and administratively burdensome monitoring and reporting requirements. There is also scope to build on the work of the World Bank's Partnership for Market Implementation and the UN's Collaborative Instruments for Ambitious Climate Action (CiACA)

32 'Enhancing Climate Change Mitigation through Agriculture', OECD, 2019.

33 'State and Trends of Carbon Pricing', World Bank Group, 2020.

programme to help developing countries develop and strengthen carbon pricing instruments.

2.46 It is worth noting that international efforts on carbon pricing do not need to be cross-economy but can be limited to the small number of sectors that account for a disproportionate share of global emissions and produce goods that are highly tradeable. At present the iron and steel industry is responsible for around 4% of total global greenhouse gas emissions.[34] Steel is an intensively traded product, with over 25% of the 1.7 billion tonnes of steel produced in 2019 crossing national borders, with production focused in a few key countries.[35] Methods for producing low-emission steel have been identified, but international agreements that accelerate the adoption of these technologies and create markets for low-emission steel products (for example standards and procurement) across trading partners could make a significant difference to carbon leakage risk.

## Box 2.A: Evolving international context

As climate ambition has continued to grow, there has been an increased international focus on the risks of carbon leakage. For example, the Italian G20 Presidency has been very active on this issue,[36] and various international organisations have made important contributions.[37] In parallel, a number of proposals have been put forward that have the objectives of addressing these risks and boosting international action on emissions mitigation.

In June 2021, the IMF published its updated proposal for an International Carbon Price Floor (ICPF)[38] to support the commitments made by countries under the Paris Agreement.

The IMF suggests establishing a minimum price of carbon to help reduce the risk of carbon leakage, and drive global decarbonisation. Although it could be implemented in different ways, the key features of the IMF's proposal are:

- **A single common carbon price but differentiated by income level**. This aspect of the proposal aims to recognise the different stages of decarbonisation in different countries, and the Paris agreed concept of common but differentiated responsibilities. At the same time, the higher the differential in carbon prices between participating countries, the lower the effectiveness at reducing carbon leakage risk;
- **A limited number of countries and sectors**. The proposal initially seeks to bring together a small set of the largest emitters, focusing

34 'Accelerating the Low Carbon Transition', Brookings, 2019.

35 Over 75% of steel production comes from the 6 main producing countries - China, India, Japan, United States, Russia, South Korea. World Steel Association, 2020.

36'International Conference on Climate Change in Venice: Press release No 142', MEF, 2021.

37 See for example the joint OECD and IMF report, for the G20, on 'Tax Policy and Climate Change' OECD and IMF, 2021.

38 Proposal for an international carbon price; IMF, 2021.

on sectors already covered by existing carbon pricing policies, with the potential to be expanded across countries and sectors; and,

- **Recognising implicit and explicit carbon pricing efforts**. The IMF proposes the recognition of both explicit carbon pricing and regulations. This would require a framework for assessing the equivalence of different measures.

In August 2021, Germany published the latest iteration of its thinking on co-ordinated international carbon pricing approaches; an international climate club. It is predicated on a view that 'it is not possible to tackle climate change successfully at the level of individual countries or of the EU' and that the establishment of an open, collaborative climate club could 'set joint minimum standards, drive climate action that is internationally co-ordinated and ensure that climate action makes a country more competitive at the international level.'[39]

This proposal emphasises the need for an inclusive approach. It would include agreement among the group of a uniform analytical approach to calculating implicit and explicit carbon prices and to measuring the carbon footprint of goods, with members agreeing a carbon price floor to apply across the group in agreed sectors with joint carbon leakage policies in respect of non-members. It would also include co-operation in research and development, including green hydrogen, and climate financing. The stated goal is for as many countries as possible to support joint climate policy measures, taking into account the particular challenges for developing countries.

## Free allocations, subsidies and revenue recycling

2.47 Free allocation of UK Emissions Trading Scheme (UK ETS) allowances is the main policy instrument through which carbon leakage risks are currently addressed in the UK ETS. While firms granted these allowances still participate in the ETS, and should still have the incentive to abate if they can do so more cheaply than the price of an allowance which they could sell, these firms may just use these allowances to carry on emitting. These free allocations provided to industry through the UK ETS are worth several billion pounds a year, based on recent prices. The EU also uses free allocations to mitigate against the impacts of carbon leakage within its ETS and is seeking to better target the provision to those most at risk. For industrial sectors less exposed to carbon leakage, free allocations are foreseen to be phased out in the EU ETS by 2030. Under the UK ETS, free allocations will be decreasing throughout the 2020s and the UK government and Devolved Administrations are committed to reviewing free allocation policy. The UK ETS Free Allocation Review, which launched in April this year with a call for evidence, aims to ensure free allocations are better targeted, specifically in the context of the setting of a net zero consistent emissions cap.

[39] 'The German government wants to establish an international climate club: Press release, Number 23', Federal Ministry of Finance, 2021.

2.48 Another option to mitigate the carbon leakage risk created by the increased business cost of climate policy is for the taxpayer to bear some of that cost through targeted support. This approach runs counter to the principle of polluter pays, so there must be robust evidence of risk and a high bar for support, which must be targeted.

2.49 Further measures to support decarbonisation through public investment would need to be traded-off against other capital investment projects or funded through additional taxes. This approach is necessary given the fiscal pressures that will materialise across the transition, to ensure sustainable public finances, to provide the public with the best value for money and to address market failures and barriers to decarbonisation. The government may choose to use revenues collected from carbon pricing to help the most at-risk sectors to decarbonise, although in practice trade-offs would have to be made with how the money could otherwise be spent. Any spending measures would also need to be WTO compliant.

## Carbon Border Adjustment Mechanisms

2.50 Debates around the potential use of Carbon Border Adjustment Mechanisms (CBAMs) are increasingly prominent, with the European Commission publishing its legislative proposals this summer (see Box 2.B), and Canada actively considering the potential merits of CBAMs. A CBAM is "a measure applied to traded products that seeks to make their prices in destination markets reflect the costs they would have incurred had they been regulated under the destination market's greenhouse gas emission regime."[40]

### Box 2.B: European Commission's CBAM proposal

In late 2019, the European Commission announced[41] that it would propose a CBAM to mitigate for differences in climate ambition between the EU and trade partners by putting an additional carbon price on emissions[42] embodied in selected imports. The Commission's draft legislative proposal for a CBAM was released on 14 July 2021,[43] proposing a 'notional' extension of the EU ETS to imports[44] through a system of CBAM certificates.

The European Commission is currently working to pass the legislation by 2023, although the proposal includes a 'transition period' of three years,

[40] 'A Guide for the Concerned: Guidance on the elaboration and implementation of border carbon adjustment, International Institute for Sustainable Development', Cosbey, A. et al., 2012.

[41] 'Communication from the commission to the European Parliament, The European Council, The Council , The European Economic and Social Committee and The Committee of the Region: The European Green Deal, European Commission, 2019

[42] The EU's proposed CBAM would cover direct emissions from the production of these goods (emissions that the producer has direct control over, including emissions from heating and cooling processes used during the production process) with the possibility to further extend the scope of embodied emissions to indirect emissions at the end of the transition period

[43] Regulation of the European Parliament and of The Council: establishing a carbon border adjustment mechanism, European Commission, 2021.

[44] The legislative proposal covers steel, iron, cement, fertilisers, aluminium and electricity.

during which there would be reporting requirements, but no CBAM charges. CBAM charges are envisaged as starting when the full system becomes operational in 2026, in conjunction with the phase out of free allowances under the EU ETS.

CBAM policy development will be complex, and as the proposal evolves the government will continue to evaluate the impact on the UK and engage with the EU accordingly.

2.51 Any carbon-specific policies affecting trade introduced by a WTO member would need to be compliant with its international obligations, including as a member of the WTO. Carbon-specific policies applied to imports would be most effective in a policy sense (i.e. at mitigating carbon leakage risks) if they discriminate effectively between imported products based on an objective assessment of (1) the carbon intensity of those products and (2) the level of carbon pricing applied in the country of origin, compared to domestic carbon pricing. Any such approach would, however, need to comply with WTO rules on the treatment of 'like' products.

2.52 Beyond potential issues of WTO legality, and as with proposals for product standards, or internationally agreed measures, any proposal to introduce a CBAM for a particular product would need to consider a range of issues, including the following[45]:

- Measurement and methodological issues. The development of consistent approaches to measuring carbon emissions, and improvements in the accuracy of global carbon emissions data will be important to underpin global climate mitigation policies, and a better understanding of the nature and extent of carbon leakage risks. Any jurisdiction introducing CBAMs would also need to consider the extent to which measures other than carbon prices (such as a regulatory approach to reducing emissions) can be considered equivalent to carbon pricing, or not, when calculating the appropriate level of a CBAM;[46]
- Consumer and business impacts. The distributional impact of any CBAM proposal would need to be carefully considered, as would the implications for input costs and administrative costs for business; and,
- Substitution effects. If a country applying a CBAM accounts for a small share of an international market, rather than incentivising a reduction in carbon intensity in exporting countries, it may simply trigger substitution effects, with the most carbon intensive products redirected to alternative markets. If a country accounts for a large share of an international market then applying a CBAM will have different effects, which will tend to weaken the global effect of the mechanism. For example, a CBAM in a 'large' net-importer could lower world prices and

[45] 'Climate Policy Leadership in an Interconnected World: What Role for Border Carbon Adjustments?', OECD, 2020.

[46] Where emissions mitigation is incentivised in ways other than an explicit carbon price, it can be hard to assess the carbon price equivalence of such measures, and hence the appropriate level of a CBAM.

stimulate increased global consumption and imports into alternative markets.

### Box 2.C: The use of a CBAM in California

California's state-wide cap and trade system generated concerns about carbon leakage to neighbouring states interconnected in the electricity market. To combat this, in January 2013, California introduced a compliance obligation under the cap-and-trade program on electricity, requiring entities to surrender emissions allowances for electricity generated out-of-state in addition to that generated in-state.[47]

This policy effectively applied a carbon border adjustment on imports of electricity from other US states, which still generated 6% of total emissions in California in 2018 (compared to 9% generated from in-state electricity).[48] It has helped bring down emissions from both in-state and imported electricity since 2015. However, policy makers have found it challenging to entirely prevent resource shuffling.[49][50]

2.53 While CBAMs can have an intuitive appeal, they are not straightforward. Furthermore, the fundamental driver of carbon leakage is international trading partners moving at different speeds on emissions mitigation and carbon pricing. This means that the starting point is to work with other countries to agree and implement ambitious emissions mitigation goals.

## Product standards and procurement

2.54 Product standards and other mechanisms, which improve consumer access to information on the climate impact of purchases, can help develop the market for low carbon products and as a result go some way to mitigating carbon leakage risk. The UK government has committed to developing proposals for low carbon product standards and new product labelling for industrial products, for potential introduction by 2025, in the Industrial Decarbonisation Strategy.[51]

2.55 The use of mandatory standards is one medium-term mechanism which could be used to mitigate carbon leakage and enable reductions in industrial emissions. Mandatory standards would set an upper limit on the emissions

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47 'Including electricity imports in California's cap-and-trade program: A case study of a border carbon adjustment in practice.', Pauer, 2018.

48 'California Greenhouse Gas 2000-2018 Emissions Trends and Indicators Report', California Air Resources Board, 2020.

49 Resource shuffling refers to a situation where a supplier would seek to 'shuffle' its production, based on its relative carbon intensity. To side-step rules relating to carbon intensity it may decide to sell (or deem that it has sold) its most GHG intensive production in places where carbon regulation is less stringent and instead sell (or deem to have sold) only its least GHG intensive products into the market where rules relating to carbon intensity are applied.

50 'Leakage from Subnational Climate Policy: The Case of California's Cap-and-Trade Program', Caron et al., 2015.

51 'Industrial Decarbonisation Strategy', BEIS, 2021.

associated with products manufactured in or imported into a country's market. Advantages of mandatory product standards include the guarantee of demand for greener industrial outputs, especially if there is an alignment of product standard regulation across jurisdictions.

2.56 However, mandatory product standards share a number of limitations faced by CBAMs. They require significant data on the carbon intensity or other relevant metrics of products and outputs, both domestic and imported. Finally, as with CBAMs, they would need to comply with WTO rules on the treatment of 'like' products.

2.57 Sectoral decarbonisation with product standards should be complemented by a co-ordinated international approach to support the alignment of standards for low carbon industrial products, such as cement and steel. This would help to create the economies of scale with multiple markets sharing standards and procurement practices, motivating larger investments in low carbon production. A key forum for delivering co-ordinated action on procurement and industrial product standards is the Industrial Deep Decarbonisation Initiative under the Clean Energy Ministerial, which is co-led by the UK and India.[52]

## Domestic productivity and consumption – interactions with carbon leakage

2.58 Improvements in domestic productivity (either increased output from a given set of inputs, or the same level of output using reduced inputs) can stem from a number of factors. For example, in the agricultural sector, advances in herd genetics, pasture quality and animal husbandry have sustained significant productivity gains over time; as a result, any given level of production results in fewer emissions.[53] However, such benefits could be offset, to a degree, by rebound effects arising from behavioural responses by producers or consumers.[54]

2.59 At the same time, productivity gains tend to reduce unit costs of production, which would generally be expected to help offset the negative competitiveness impacts of emissions mitigation policies. This in turn would help mitigate the risk of carbon leakage.

2.60 Separately, reductions in the domestic consumption of carbon-intensive products, whether because of policy or changing social preferences, can also help mitigate the risk of carbon leakage. Policies, such as biofuels mandates, that increase domestic demand for agricultural products can interact with trade balances to increase emissions overseas, through a process known as indirect land use change. In the same way, reductions in domestic consumption would narrow the gap between domestic production and

52 The Clean Energy Ministerial are global forums held to promote policies and to share best practices with the aim of accelerating a transition to clean energy. The current 26 members of the CEM account for 90% of the world's clean power and 80% of global clean energy investment.

53 'Making Better Policies for Food Systems', OECD, 2021.

54 'Rebound effects in agricultural land and soil management: Review and analytical framework', Journal of Cleaner Production 227, 1054-1067, Carsten P et al., 2019.

consumption, and reduce the scope for carbon leakage should domestic production then fall as a result of domestic emissions mitigation.

## While carbon leakage risks can be mitigated, a one size fits all approach should be avoided

2.61 All options for mitigating carbon leakage risks come with a range of advantages and disadvantages. In addition, the specifics of sectors vary a lot, even among those that are tradeable and carbon-intensive. Therefore, a policy response that works for one sector, will not necessarily be appropriate for another sector. At the same time, parity of policy approach is important to avoid shifting demand between sectors - balancing these risks will be important as the UK develops its policy approaches.

2.62 Furthermore, both technology and the level of emissions mitigation effort in trading partners may change over time, possibly abruptly, which could change the levels of leakage risk in any given sector, and potentially the balance between different mitigating options. Given this, options should be kept under review.

## A framework for dealing with leakage risk

2.63 The UK takes the risk of carbon leakage seriously. As it introduces policies to meet its emissions mitigation targets, active consideration will therefore need to be given to the full range of possible measures, including novel and innovative approaches, which could help to address carbon leakage. Such measures would need to be considered taking into account the following:

- **The risk to our global climate goals.** Although carbon leakage manifests itself through competitiveness impacts, it is primarily an environmental concern. Therefore, mitigations should be proportionate to the size of the climate risk;
- **The distinction between carbon leakage and wider structural changes to the global economy.** Globally, economic structures vary and are constantly changing, meaning that production can shift from one jurisdiction to another for a wide range of reasons. To tackle carbon leakage effectively, any policy should be dynamic, evolving as sectors evolve, and based on evidence that disentangles these effects from the impact of differentials in climate policy between trading partners;
- **The scope for tackling the root cause of carbon leakage risk, working collaboratively in the first instance where possible.** Carbon leakage is caused by different countries taking divergent approaches to climate change mitigation, in particular through differentials in carbon prices – explicit or implicit. As such, the best solution would be effective international action. The first step is to encourage our trading partners to mitigate climate change, as ambitiously as possible, by reducing their emissions through measures such as implementing and co-operating on carbon pricing regimes, standards, market creation measures and research and development;
- **The need to maintain a stable, coherent policy landscape based on targeted intervention.** Any policies implemented to mitigate the carbon

leakage risk must be targeted to the specific and evidenced risk faced by each sector; and,

- **Ensuring value for money for taxpayers while minimising business and consumer impacts.** Policies implemented to mitigate carbon leakage will need to consider business, consumer and taxpayer impacts in the round.

## Further work is required

2.64 This section has drawn on OECD data and set out a range of considerations and policy options in respect of carbon leakage. This is an important area, with considerable uncertainties and significant data gaps. However, what is clear is that if action to mitigate domestic emissions merely displaces emissions to other jurisdictions with higher carbon intensities, then the environmental objectives underlying net zero will be undermined.

2.65 Therefore, HM Treasury, working with other government departments, will continue to work to develop: its understanding of the risks of carbon leakage; the relative merits of, and potential timelines for, different policy responses; and, the implications of actions that may be taken by other jurisdictions to address concerns about carbon leakage. International co-operation on viable measures that would encourage further collective mitigation action and tackle carbon leakage make most sense, both economically and environmentally. However, such measures require time to develop and implement and may, in some instances, fall short. HM Treasury will continue to engage on these issues with our international partners, but also with those domestic sectors where the risks of carbon leakage are most pronounced, and others who can provide insights in this complex area. As this work proceeds, a case for conducting a formal call for evidence may emerge. In making that judgement, the government would take into account a range of factors, including international progress implementing the Paris Agreement.

# Chapter 3

# Understanding households' exposure to the net zero transition

The costs and benefits from the transition to a net zero economy will pass through households – directly as billpayers, motorists or homeowners, and indirectly as consumers, employees, business owners or taxpayers. However, the transition will be dynamic, and the costs and benefits will not fall evenly across households. As the UK continues to decarbonise, it will be important to take account of the factors that influence the distribution of costs and benefits.

Assessments of abatement costs in the future are highly speculative. It is, therefore, not possible to forecast how individual households will be affected over the course of a 30-year transition with accuracy. While income is important, there is significant variation within income deciles. A household's characteristics will have a significant influence on the level of their exposure to the transition; for example, whether they use a car, the type of property they live in, and where they work.

Given the importance of household characteristics in determining a household's exposure to the transition, and the degree of that exposure, it will be more effective to focus taxpayer support on specific groups and their abatement costs, rather than consider untargeted spending, or changes to the tax and welfare system. The government will continue to support households through the transition as set out in the Net Zero Strategy and the Heat and Buildings Strategy.

## Overview

3.1 The costs and benefits of the transition to a net zero economy will ultimately pass through to households through a range of different channels.

3.2 Some costs will be borne by households directly:

- the cost to households of adopting new low carbon technologies. For example, investing in new central heating systems or buying zero emissions vehicles; and,
- any carbon price applied to their ongoing emissions.

3.3 Similarly, businesses may incur costs arising from investing in – and running – new low carbon technologies or paying a carbon price on polluting activities. They may also benefit from technological and productivity improvements.

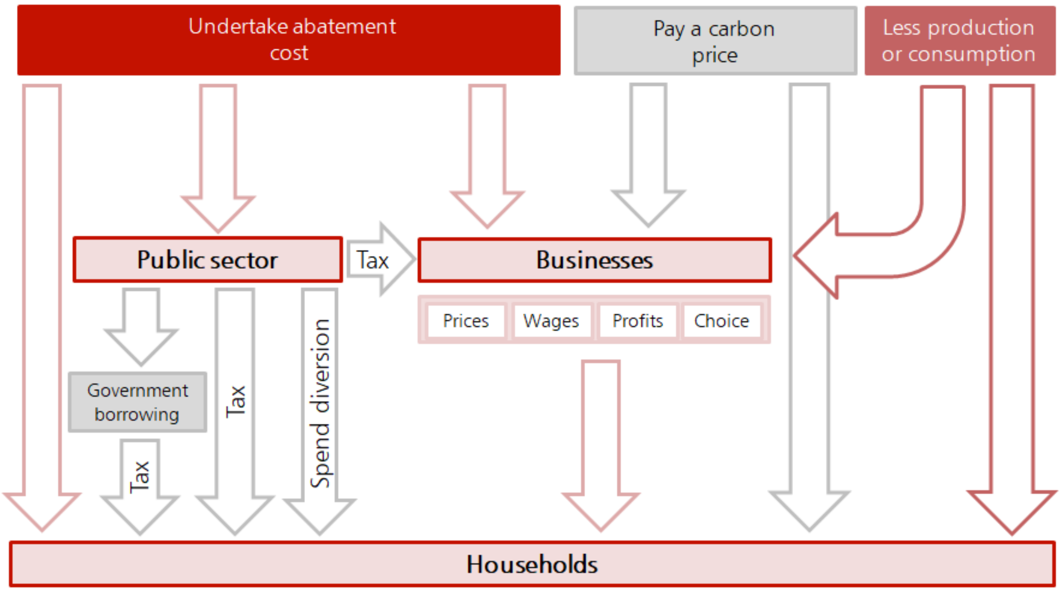
These impacts will also be passed through to households via different channels:

- the price and choice of goods and services available to households; and,
- profits and wages that accrue to households as business owners and employees.

3.4 Finally, the cost of government-funded programmes will also be met by households through their taxes, or through lower public spending (and reductions in public services) in other areas. How these costs are distributed across different households will be influenced by government choices, including with regard to the tax system.

3.5 Chart 3.A summarises how the costs and benefits of decarbonisation pass through to households directly as consumers and as taxpayers if the public sector funds some of the costs of decarbonisation, or indirectly through businesses and their decisions about prices, wages and profits.

## Chart 3.A: Transmission of costs to households




3.6 Some costs of decarbonisation may not fall on UK households. For example, a foreign-owned company operating in the UK could pay for abatement costs through lower profits in the country in which it is registered. However, these effects are likely to be small relative to the total costs of decarbonisation. In addition, assuming other countries are also decarbonising, these avoided costs may be offset by reductions in profits of UK companies operating abroad. Discussions of carbon leakage and policy approaches were discussed in Chapter 2.

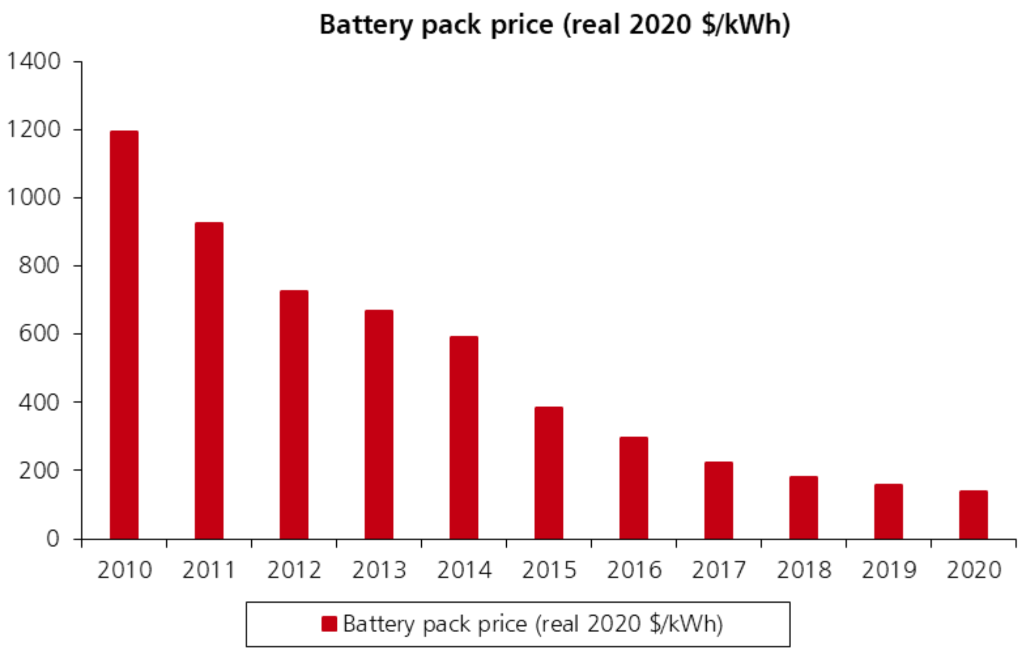
# It is not possible to forecast household impacts

3.7 The transition will be dynamic and take place over thirty years. Consequently, it is not possible to forecast impacts on households. The eventual impact will depend on policy choices and the way the economy adjusts over time, as well as a range of factors, such as technological development, efficiency improvements, consumer preferences, interest rates and income growth over the next thirty years.

## Abatement costs are speculative, although technology costs have typically fallen faster than anticipated

3.8 The net zero transition will entail a number of technology transitions, and there is significant uncertainty in relation to their costs. The UK may be using technologies in 2050 that have not been deployed at scale yet, [1] and the costs of new technologies tend to fall as they become more developed and are deployed more widely. These cost reductions can be driven by several factors, including the learning-by-doing process, economies of scale and R&D spillovers,[2] the latter of which refers to the process in which individuals can benefit from the knowledge created by others from investment in R&D.[3] Cost reductions can already be seen in key net zero technologies, such as lithium-ion battery technology, where battery pack prices have fallen by nearly 90% in real terms between 2010 and 2020.[4]

### Chart 3.B: Lithium-ion Battery Price Changes




*Source: BloombergNEF*[5]

[1] The International Energy Agency (IEA) estimates that in 2050 almost half of CO2 emissions reductions will come from technologies currently at the demonstration or prototype stage. 'Net Zero by 2050, A Roadmap for the Global Energy Sector', IEA, 2021.

[2] 'Wright meets Markowitz: How standard portfolio theory changes when assets are technologies following experience curves', Journal of Economic Dynamics and Control, Volume 101, R, Way, F. Lafond, F. Lillo, V. Panchenko and J. D. Farmer, 2019.

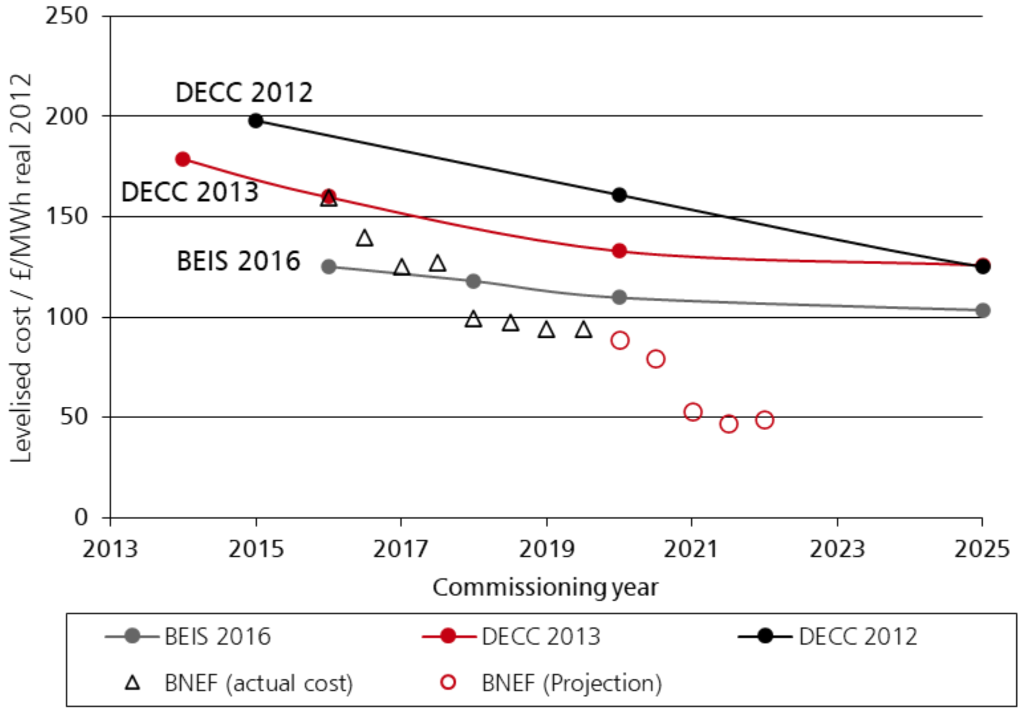
[3] 'Cumulative Innovation and Dynamic R&D Spillovers', Colino, 2016.

[4] 'Battery pack prices cited below $100/kWh for the first time in 2020, while market average sits at $137/kWh', Bloomberg New Energy Finance, 2020.

[5] '2020 Lithium-ion Price Survey', BloombergNEF, 2020.

3.9 It is inherently difficult to predict future technology and innovation costs. In the past the costs of renewable energy technologies, for example, have been overestimated as their costs have fallen faster than government and other organisations had predicted. Chart 3.C highlights this and illustrates how the projected costs of offshore wind projects were far higher than the actual costs of projects in the corresponding year.

### Chart 3.C: Projected vs actual costs of offshore wind projects




*Source: Department for Energy & Climate Change, BEIS, BNEF*[6]

## Current carbon consumption patterns could help to indicate potential household exposure to the transition

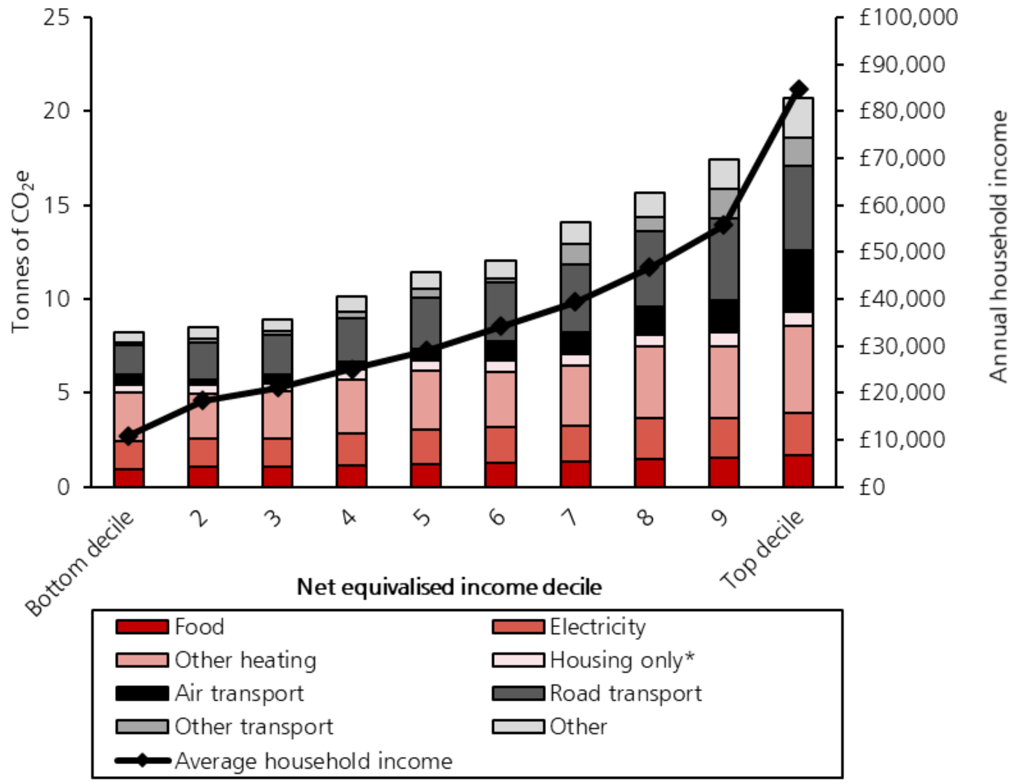
3.10 A household's exposure to the transition will depend on their characteristics such as whether they use a car, the type of property they live in, and where they work. These characteristics may change as consumer preferences and lifestyles change. Consequently, it is not possible to forecast how individual households will be affected over the course of an economic transition that is expected to take 30 years to complete. However, recent carbon consumption patterns can help to develop a provisional picture of which households could be most exposed in the transition, and which may face the highest costs. This can then help to inform future policy to support those households which could be particularly exposed to the costs of the transition, so they will not be disproportionately affected.

3.11 Chart 3.D shows the carbon footprint associated with households' consumption across income deciles, based on 2016 carbon emissions. Higher

[6] 'DECC Electricity Generation Costs', DECC, 2012 and 2013; 'BEIS Electricity Generation Costs', BEIS, 2016; 'BEIS electricity generation cost report (2020)', BEIS, 2020; 'Historic LCOE', BNEF, 2020.

income households consume more carbon than lower income households in absolute terms, but less relative to their income.

## Chart 3.D: Average household greenhouse gas footprint by net equivalised household income decile




*Housing only shows emissions associated with housing that are not heating or electricity related, such as furnishings and household maintenance.

*Source: HM Treasury calculations*[7]

3.12 Although the highest income households emit around three times as much carbon as the lowest income households, they have incomes that are more than eight times greater on average. This largely reflects a higher saving rate among higher income households, which reduces their total consumption relative to their income.

3.13 Housing and utilities are the most important sources of emissions for lower income households, making up around half of their emissions, compared to around one third for the highest income households.

## Significant variation within income deciles means policy should focus on household characteristics

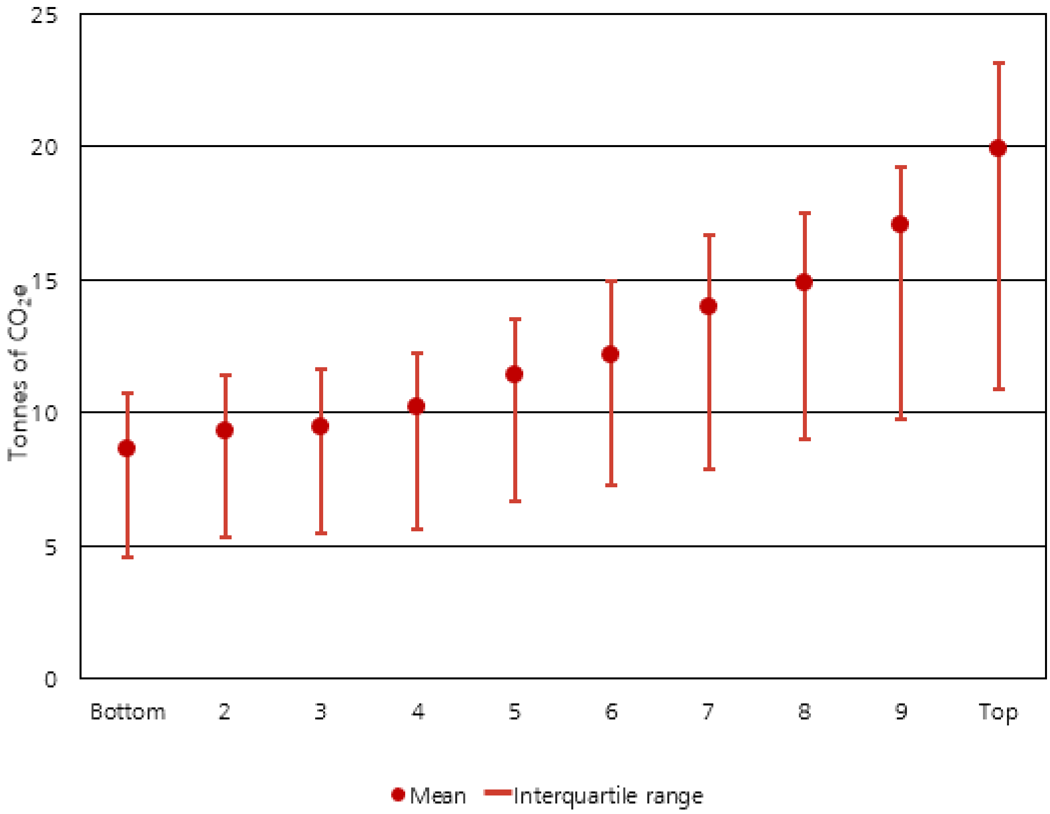
3.14 Household characteristics have a significant influence on a household's exposure to abatement costs. One of the drawbacks in considering the transition in aggregate is that the averages mask the significant variation within income deciles as a result of household characteristics. For example,

[7] LCF data, 'UK's Carbon Footprint' (2016 data), DEFRA, 2020.

Chart 3.D masks the true exposure across and within income deciles to the electric vehicle transition: just 35% of the lowest income decile own a car, compared with over 90% for the top four deciles. [8]

3.15 Given this, Chart 3E shows another approach to quantifying the level of variation in households' exposure to abatement costs. It presents average greenhouse gas emissions by household income decile, as well as the interquartile range of greenhouse gas emissions within each decile (the range occupied by the middle half of households, if those in each decile are ranked in order of their emissions). This shows that the difference in average emissions between deciles is of a similar magnitude to the variation in emissions within some individual deciles: for example, the difference in average between the highest and lowest-income deciles is 11.2 tonnes of $CO_2e$, whereas in the highest-income decile the interquartile range is 12.3 tonnes of $CO_2e$.

## Chart 3.E: Average household greenhouse gas footprint, and interquartile range, by net equivalised household income decile




*Source: HM Treasury calculations*[9]

3.16 The degree of variation in emissions within each income decile is large because it is associated with household characteristics – such as vehicle usage and housing type – which are themselves highly variable within income deciles. Consequently, it will be important to consider specific technology transitions, and the factors that affect the degree to which a household is exposed and

[8] Percentage of households with cars by income group, tenure and household composition in 2018: Table A47, ONS, 2019.

[9] LCF data, 'UK's Carbon Footprint' (2016 data), DEFRA, 2020.

how soon they are able to enjoy the benefits of the new technology. These are explored in Chapter 4.

## Policy implications

3.17 Universal grants or changes to the tax and welfare system will not be effective solutions in managing adverse distributional impacts. Untargeted policies are likely to lead to taxpayers providing most support to the wealthiest and most polluting households to reduce their emissions, because they emit more in absolute terms. Changes to the tax and welfare system would present ongoing costs to the taxpayer in order to address largely one-off transition costs, and lead to high deadweight costs given the variation in household characteristics within income deciles.

3.18 Instead, reflecting the significant variation in household characteristics within income deciles, public spending should be targeted at specific decarbonisation measures for low-income households. Where this leads to lower running costs, it will also provide an ongoing benefit to the households receiving taxpayer support. This targeted approach is reflected in a number of government schemes, as set out in the Heat and Buildings Strategy.

## Chapter 4

# Factors affecting the degree of household exposure to the power, housing and electric vehicle transitions

Household characteristics influence a household's exposure to the overall transition to net zero. Within each individual technology transition, there are a range of factors that affect the degree to which a household is exposed, and how soon they could start to realise the benefits of the UK's new low carbon economy. This chapter will look at power, housing and electric vehicles as key areas where consumers may face costs and enjoy benefits during the transition.

### POWER

As the economy transitions to net zero, emissions from the power sector will need to be reduced significantly, but there will also be increased demand for green power. Together, this could require a four-fold increase in green generation. Households have largely funded this investment through their energy bills to date, and their exposure to power decarbonisation costs will depend on the domestic unit price of electricity and their total energy consumption, both of which are uncertain over the transition period:

- The future price of electricity is highly uncertain. Based on current policy and long-term forecasts, average household unit electricity prices could look broadly stable over the next thirty years. This is because large capital investments will be spread over a larger user base, as power consumption replaces fossil fuel consumption across heating, transport, and industry; and,
- Households' energy consumption will change over the transition. As products are electrified, energy bills across power, heating and transport may rise or fall compared to current bills. Future consumer bills will depend on car ownership, low carbon heat technology choices, energy tariffs and consumer behaviour.

### HOUSING

Decarbonising heat and buildings will mean households install energy efficiency measures and replace fossil fuel heat sources, like natural gas boilers, with green alternatives. The channels through which households may be exposed to the decarbonisation of residential property over a 30-year period are complex. Analysis suggests:

- Households' exposure will depend on a number of factors including dwelling size, with larger properties facing higher costs, and dwelling type, as detached properties are likely to require twice the investment of a high-rise flat;
- For renters, exposure to the transition will be influenced by the degree to which landlords meet upfront costs themselves or pass them through to their tenants; and,
- Addressing the imbalance between gas and electricity prices is likely to be important in helping key technologies such as heat pumps become a more attractive consumer proposition. The government will launch a Fairness and Affordability Call for Evidence to help rebalance electricity and gas prices. In addition, the government will work with industry to seek to reach cost parity between heat pumps and gas boilers by 2030.

## ELECTRIC VEHICLES

Road transport makes up a significant proportion of the average household's costs and carbon emissions, so whether or not a household owns and uses a car or van will be an important factor in determining their overall exposure to the transition.

The costs and benefits of owning electric vehicles (EVs) will change over time. While EVs are currently more expensive to buy than the equivalent petrol or diesel car, their costs are falling rapidly and could reach upfront price parity by 2030 or earlier. Drivers of EVs also face lower fuel and maintenance costs. In addition, the development of the charging network over the next thirty years will be important in determining how the cost of charging eventually affects households. Different households will be exposed to the transition at different points in time:

- As higher income households drive more and are likely to adopt EVs earlier, the costs and benefits of EV adoption are likely to fall on higher income households first;
- Conversely, any changes to the cost of running an internal combustion engine (ICE) vehicle will fall disproportionately on lower income households, so there could be a trade-off in some instances between incentivising decarbonisation and mitigating distributional impacts; and,
- Car usage varies by geography, income and age, which will influence how soon the benefits of the EV transition could be experienced.

# Overview

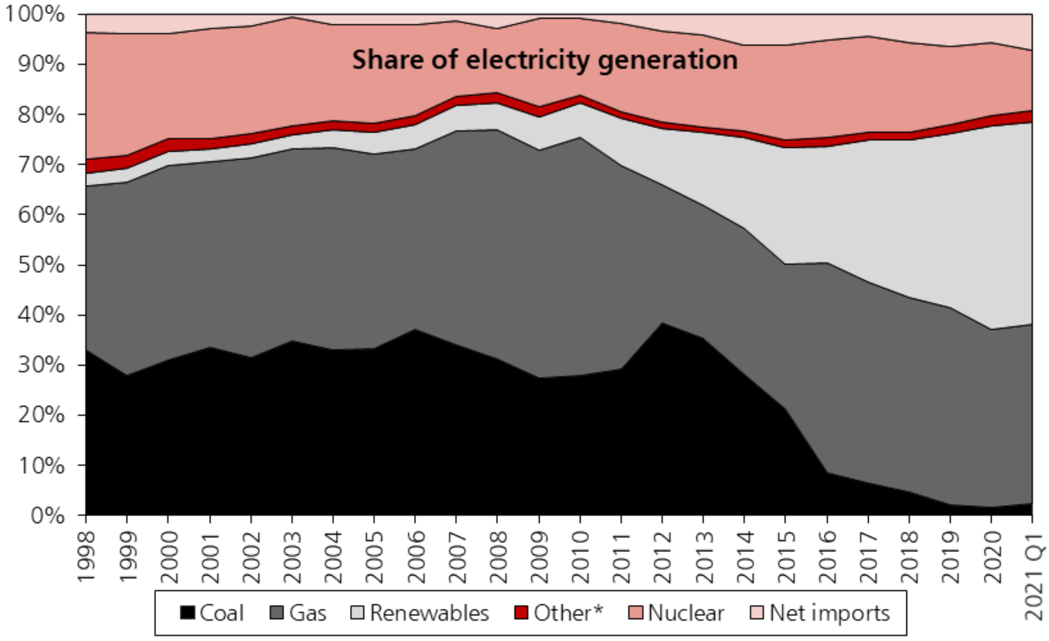
4.1 Household characteristics influence a household's exposure to the overall transition to net zero. Within each individual technology transition, there are a range of factors that affect the degree to which a household is exposed, and how soon they could start to realise the benefits of the new green economy. This reflects the complex nature of the transition to net zero, and the range of issues that will need to be considered when designing policy in the future.

# Power

## Overview

4.2 Decarbonising the power sector has led the UK's efforts to reduce greenhouse gas emissions: emissions intensity has already fallen 68%,[1] largely due to the reduction in the use of coal. Energy supply accounts for 21% of the UK's greenhouse gas emissions.[2] Green technologies currently provide over half the power for the UK, as shown in Chart 4.A. The rapid growth of renewables has been a central element of this transformation.

### Chart 4.A: Change in power supply: fuel used in electricity generation and electricity supplied




*Other includes oil, pumped storage and other thermal generation.

*Source: BEIS*[3]

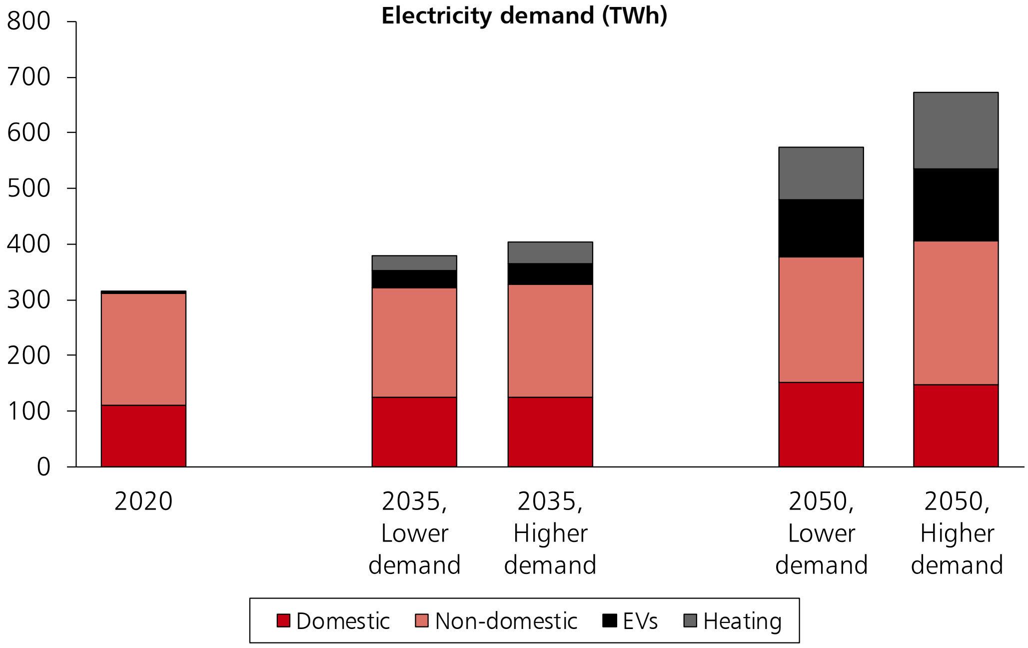
[1] 'The Sixth Carbon Budget, Electricity Generation', CCC, 2020.

[2] '2019 UK greenhouse gas emissions, final figures', BEIS, 2021.

[3] 'Energy Trends: UK electricity, Table 5.1, BEIS, 2021.

4.3 The Department for Business Energy and Industrial Strategy (BEIS) scenario analysis suggests that by 2050 electricity demand could double,[4] as shown in Chart 4.B. This is predominantly due to the increased adoption of electric cars and vans, and increased electrification of heating in place of gas. Consequently, electricity may account for more than half of final energy demand by 2050, increasing from 17% in 2019. This rise in demand will require a four-fold increase in low carbon generation.

### Chart 4.B: Illustrative electricity demand; net zero scenarios




*Source: BEIS analysis*[5]

4.4 The cost of decarbonising power can be reduced though a smart, flexible energy system, which utilises technologies such as storage, flexible heating systems, smart electric vehicle charging and interconnection. This optimises low carbon power and reduces how much generation and network capacity is required to meet peak demand. BEIS estimate that increased flexibility could reduce system costs between £30 billion to £70 billion between 2020 and 2050.[6]

## Factors affecting households' power sector costs

4.5 Through their electricity bills, households have funded schemes to attract private finance into renewables, providing revenue streams that have enabled the rapid development of record amounts of new, green generation. This investment and structural change in power generation has meant that many green technologies that generate power and heat are now cheaper than their fossil fuel counterparts. Energy consumers have also contributed to keeping

[4] Note: the CCC also estimate electricity demand doubles to 2050, reflecting electrification of sectors across the economy. 'Energy White Paper', BEIS, 2020.

[5] Note: The chart outlines illustrative electricity demand scenarios. However, electricity demand in 2050 may be higher than illustrated in the chart. 'Energy White Paper', BEIS, 2020.

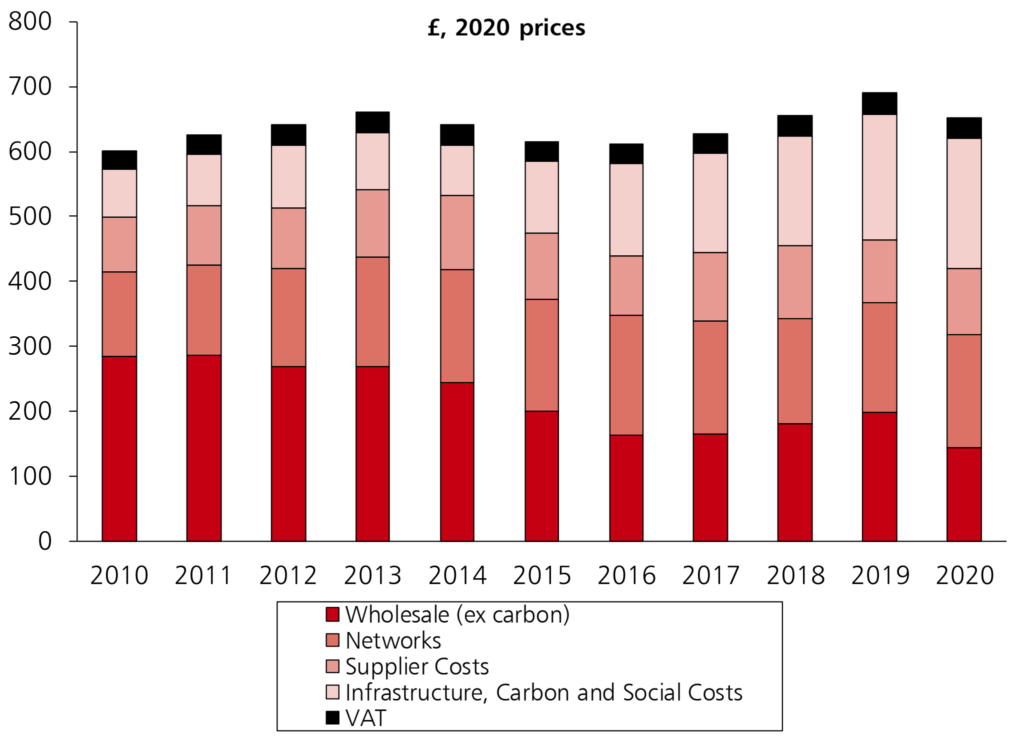
[6] 'Transitioning to a net zero energy system', BEIS, 2021. 2012 prices, discounted.

the system fairer and more affordable, by providing financial support to vulnerable households and industries through government-mandated social schemes.

4.6 The levies on consumer bills have changed the composition of the typical household bill over the past decade, even as total bills have been broadly flat (Chart 4.C). Between 2010 and 2020 the composition of the average bill has seen the following changes[7]:

- **Wholesale costs,** while still dependent on gas prices and volatile from year-to-year, in general have fallen as a share of the household bill since 2010. This is due to increasing low carbon electricity generation;
- **Network costs** were 20% higher in 2020 than in 2010, reflecting the increased investment needed in networks over this period; and,
- **Infrastructure, carbon and social costs** have nearly tripled since 2010, as investment in renewables has increased.

## Chart 4.C: Average annual household electricity bill, 2010 to 2020




*Source: BEIS analysis*

4.7 As set out above, household electricity bills were slightly higher in 2020 in real terms than in 2010. However, while domestic electricity prices have risen since 2010, improved energy efficiency has reduced average consumption, and this has partially offset the rise in prices.

4.8 Future household bill impacts will depend primarily on the domestic unit price of electricity and a household's total energy consumption, both of which are uncertain over the transition period.

[7] 'Energy White Paper, Powering our Net Zero Future', BEIS, 2020.

## The future price of electricity is uncertain

4.9 Projecting future electricity prices is challenging as there are several key uncertainties that will influence them. This makes it difficult to predict how prices and bills may change over the coming decades. For example:

- **There is technological uncertainty**: for example, the future role of hydrogen in decarbonising electricity, and its use in heating, is currently unknown and could significantly change the cost of the power system. Equally, the cost and deliverability of many other technologies (such as Small Modular Reactors, and Biomass with Carbon Capture and Storage) is also uncertain;
- **There is policy uncertainty**: decisions made by the government and regulators will have an impact. The future electricity generation mix – between renewables, nuclear and carbon capture, utilisation and storage (CCUS) – is not known and will be subject to market forces and government decisions. The final mix, and the effectiveness with which green generation is integrated together through new networks and complementary flexibility, will have cost implications for the energy system. The future retail market and consumer tariffs are also uncertain;
- **There is price uncertainty**: Contracts for Difference strike prices,[8] wholesale prices, and hydrogen prices could have a sizeable impact on electricity bills;
- **There is energy demand uncertainty:** future electricity demand will depend on energy efficiency in part, but the future efficiency of heat pumps and electric vehicles is unclear. It is also uncertain how changing consumer behaviour over thirty years may affect the structure of household bills in 2050. For example, flexibility in the consumption of energy[9] could result in changing tastes and lower bills; and,
- **Wider economic factors:** it is challenging to forecast changes to global commodity prices, and economic activity over a 30-year period.

4.10 Based on a scenario in which current policy is held broadly constant, BEIS analysis of the Sixth Carbon Budget scenarios suggests that average domestic unit prices for electricity could look broadly stable over the next thirty years. This is because large capital investments will be spread over a larger user base, as power consumption replaces fossil fuel consumption across heating, transport, and industry. Should the power system move from a high operational costs structure to one based on high capital expenditure and low operational costs, wholesale costs are expected to fall due to increased zero marginal cost generation. The associated capital costs and network investments within electricity prices however will increase. As noted above, there is significant uncertainty around future electricity prices and if policy decisions change the structure of support, future electricity prices will look very different.

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[8] At the 2015 Contracts for Difference allocation round (auction), the strike price for offshore wind was £120, in 2017 it was £57.50, and in 2019 it was £40 (all in 2012 prices).

[9] Consumers could sign up to tariffs which reward them for changing how and when they use electricity. Smart meters and other technologies such as flexible heating systems paired with energy storage will make flexible consumption of energy easier.

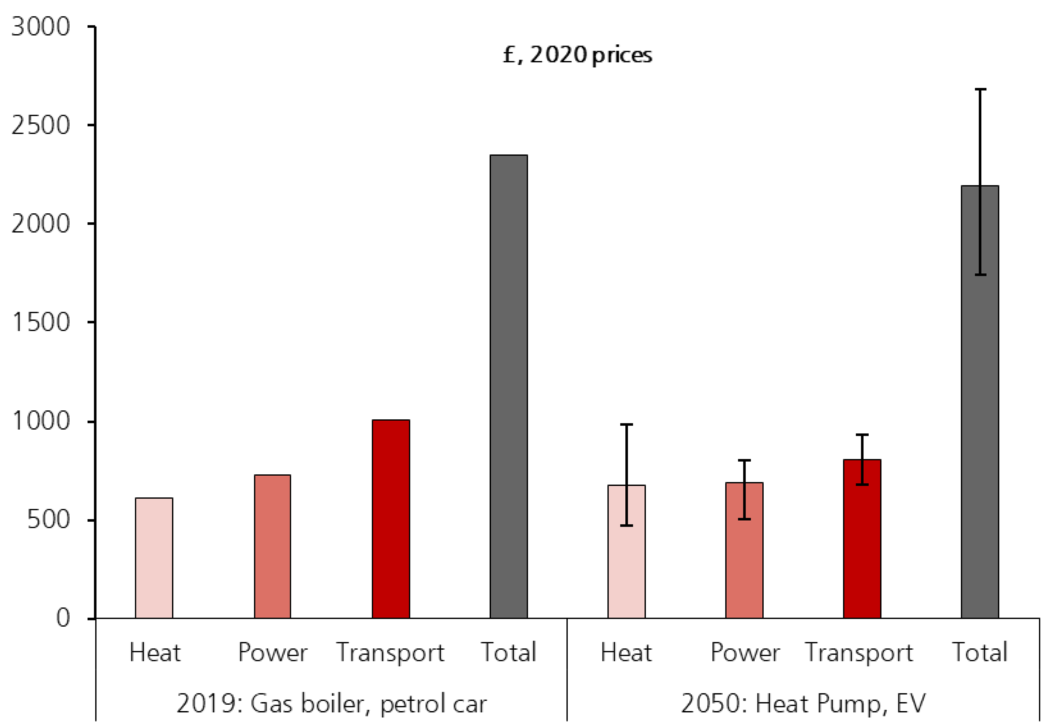
## Households' energy consumption patterns will evolve

4.11 Projecting energy bills into the future is inherently uncertain. The analysis presented in this report presents one of many states of the world.[10]

4.12 Under an electrification scenario, heating and transport costs will also form part of the electricity bill. Chart 4.D compares the average bill for a household with a gas boiler and a petrol car in 2019 and an illustrative average bill for a household with a heat pump and an EV in 2050.[11]

4.13 The sum of potential uncertainties considered amounts to a range that is almost half of the bill estimate in 2050. Most of the uncertainty surrounds future heating, where uncertainty in the technological efficiency of heat pumps compounds home efficiency and the base demand for heating. In addition, increased demand for electricity amplifies the uncertainty in electricity prices.

### Chart 4.D: Annual household power, heating and private vehicle costs




*Source: BEIS analysis*[12]

[10] There is insufficient policy detail covering energy demand to appropriately model bill impacts. Precise bill impacts for individual households will depend on several additional factors including consumer characteristics, fuel choices and policy eligibility.

[11] This scenario holds total revenues from transport taxes constant to illustrate changes in economic costs. Only those policies with agreed funding and developed to a sufficient degree of detail are included in the analysis. For the purpose of this analysis, transport taxes are assumed to be replaced like-for-like in 2050.

[12] This is scenario analysis that assumes transport taxes are replaced like-for-like in 2050. The range of uncertainty covered does not account for all factors that drive uncertainty in future bills. Most importantly, the evolution of future funding mechanisms, wider taxation decisions, and the level of government support, together with the decarbonisation pathway and the role for hydrogen and green gas, could mean that the actual range of uncertainty in future bills is much higher.

4.14 Overall household bills, across power, heating and transport, may rise or fall compared to energy consumption prior to electrification.[13] This is because impacts will vary considerably between households, notably depending on car ownership, green heat technology choices, building efficiency, energy flexibility and tariffs. This chart looks only at annual bills; it assumes that the costs of green technology can be smoothed across the lifespan of the asset and requires no front-loading or additional set-up costs.

4.15 Policy choices will also influence how costs are spread across consumers. Applying a polluter pays approach to decarbonising fossil fuels may be efficient, but there are some groups for whom a different approach may be justified, particularly households at risk of fuel poverty. The government will launch a Fairness and Affordability Call for Evidence to help rebalance electricity and gas prices and to support green choices, with a view to taking decisions in 2022.

# Housing

## Overview

4.16 In 2019, residential housing in the UK produced 69 $MtCO_2e$, and was responsible for 15% of UK greenhouse gas emissions.[14] While some of the technological solutions to enable domestic buildings to reach net zero are relatively well established, the costs and practical challenges of doing so are significant.

4.17 One of the main ways of decarbonising domestic buildings is to replace gas heating, which most dwellings currently use, with greener alternatives such as heat pumps. For these to be most effective and cost efficient, significant energy efficiency improvements will also be required in most properties. Storage technologies such as hot water tanks and batteries can also reduce the running costs of heat pumps, while also reducing the amount of generation and network needed to meet heating demand. Alternatively, if pilots are successful, domestic hydrogen boilers may be an option for many households, although operating costs remain highly uncertain.

4.18 Reflecting the importance of decarbonising domestic residential buildings, the government has already set out a number of targets and policies to support households to reduce their emissions. The overall ambition is to improve as many homes as possible to Energy Performance Certificate (EPC) band C by 2035.[15] The government's Ten Point Plan aims to increase heat pump installation to 600,000 annually by 2028[16] and improve the energy efficiency of homes. The Heat and Buildings Strategy sets out the government's aim to phase out the installation of new and replacement natural gas boilers by 2035,

[13] Currently, UK electricity prices are higher than gas, in part due to low-carbon policy costs.

[14] Note: these figures are the emissions produced by combustion from households, excluding emissions for electricity generation which is used by households and is covered above. '2019 UK greenhouse gas emissions, final figures', BEIS, 2021.

[15] 'Improving the Energy Performance of Privately Rented Homes in England', BEIS, 2020.

[16] 'The Ten Point Plan for a Green Industrial Revolution', HM Government, 2020.

in line with the natural replacement cycle and once costs of low carbon alternatives have come down, including any hydrogen-ready boilers in areas not converting to hydrogen.

4.19 The channels through which households may be exposed to the decarbonisation of residential property over a 30-year period are complex. In addition, the cost, timing and affordability of these changes will vary across the population, including by income and housing type, and so affect the overall distributional impact of the transition to net zero. One of the main changes will be new heating systems for the home, which will require an upfront investment. However, there are significant technological,[17] policy and cost uncertainties over this time horizon. Please see Annex A for detail on variation in costs. BEIS analysis suggests that mass market deployment of heat pumps could result in a 25% reduction in upfront costs by 2025, as supply chains mature and the skills base expands, with industry suggesting that cost reductions of up to 50% are achievable through modularisation and more efficient processes. The government is working with industry to halve the upfront cost of new technology, such as heat pumps, by 2025, and achieve parity with fossil fuel boilers by 2030.

4.20 There are a number of subsidy schemes for energy efficiency and heat pumps available and in development. Since June 2020, £1.4 billion has been invested in supporting low-income households improve energy efficiency and install clean heat, such as the Homes Upgrade Grant and the Social Housing Decarbonisation Scheme. At Budget 2020, the government extended the Renewable Heat Incentive and, as part of the Heat and Buildings Strategy, has announced the Boiler Upgrade Scheme, which will provide grants for all homeowners towards the costs of heat pumps from 2022. The government's overall strategy for residential housing is set out in the Heat and Buildings Strategy. In addition, the Smart Systems and Flexibility Plan sets out how the government will facilitate the take up of smart technologies, including energy storage, to help reduce peak demand.

## Policies should look beyond income when considering how best to support households in reducing emissions from their homes

4.21 Households' exposure to the heat transition will vary. On average, higher income deciles are most exposed. This is primarily because higher income households tend to live in larger dwellings and are more likely to live in houses rather than flats, both of which are more costly to upgrade. However, there is significant variation within income deciles. This suggests that policies should look beyond income when considering how best to support households in reducing emissions from their homes.

## Retrofitting costs will vary by dwelling size, type and location

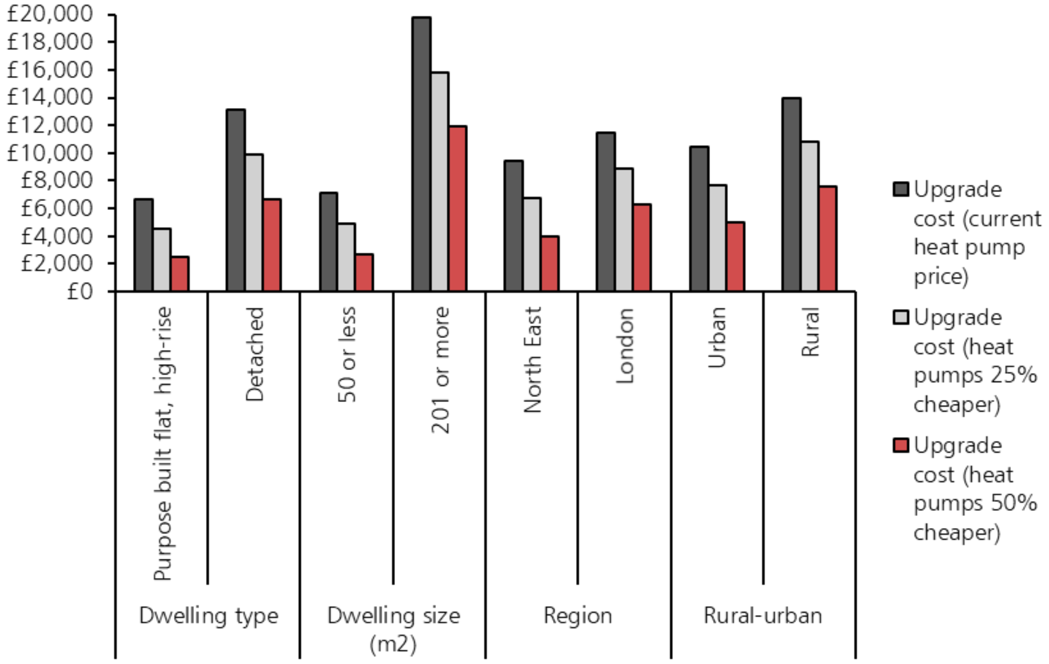
4.22 Given the likely fall in heat pump costs Chart 4.E sets out a range of scenarios. Looking at a range of dwelling characteristics, Chart 4.E shows that the largest driver of cost is likely to be dwelling size. Households living in properties 201m$^2$ or larger could be almost three times as exposed to the transition than households living in properties under 50 m$^2$. Another important factor

[17] For analysis on the impact that higher or lower costs could have, see Annex A.

affecting costs is dwelling type, with the average detached home likely to require double the investment of an average high-rise flat.[18] These factors can help explain greater exposure in rural areas compared to urban areas, as rural dwellings are more like to be larger and to be houses rather than flats.

4.23 There are also regional considerations. Chart 4.E shows that households in London could have a marginally greater exposure to the transition than households in the North East. This is mainly driven by variation in wall type (London dwellings are more likely to have solid walls, which are more expensive to insulate), and existing wall insulation provision: only 23% of London dwellings have insulated walls, compared to 73% in the North East.[19] Finally, this chart illustrates the impact that reductions in the cost of low carbon heating technologies, in this case heat pumps, could have on the cost of decarbonising buildings.

## Chart 4.E: Exposure to the transition by dwelling characteristic and heat pump cost




*Source: HM Treasury calculations*[20]

4.24 In non-standard dwellings,[21] retrofitting costs may be significantly higher. For example, the current cost estimate for cavity wall insulation of a medium-sized semi-detached houses is £590, but for non-standard dwellings, it can cost

[18] However, this analysis may be an underestimate of costs to flat owners, as they may face wider costs to ensure overall building efficiency.

[19] This does not account for regional variation in the cost of making the changes.

[20] HMT analysis of EHS and Fuel Poverty datasets, using UCL data for retrofitting and BEIS data for heat pump costs. For more detail see Annex A.

[21] A non-standard dwelling is built from materials that do not conform to the 'standard' definition. Standard dwellings have brick or stone walls with a roof made of slate or tile. A non-standard dwelling is therefore anything that falls outside of this.

£8,430 for partially filled cavity walls and £7,980 for metal or timber framed cavity walls.[22]

4.25 Listed or historic dwellings and buildings in conservation areas are also more challenging to retrofit due to the variation in building material used and a desire to ensure that retrofitting does not spoil the historic context of the building.[23] This means that costs for these dwellings are likely to be higher than average in order to achieve the same level of energy efficiency.

4.26 In addition, not all types of low carbon heating systems may be suitable for non-standard or historic dwellings, which may increase costs. Different forms of low carbon heating may be a possibility for these dwellings (for example higher temperature heat pumps, hydrogen, community heat schemes or solid biomass).

## Different household types will be exposed in different ways

### Non-owner occupiers

4.27 Some households might not pay upfront for improvements. The amount private renters pay will be affected by the extent to which landlords pass costs through to their tenants and the timing of this.

4.28 Similarly, installation costs for social tenants are more likely to be borne by social landlords, such as Housing Associations. This means that households living in social housing may be less exposed to the costs of decarbonising the housing sector (in addition, social housing is on average already much better insulated, with 62% of dwellings already having wall insulation, compared to just 32% of privately rented dwellings, reducing the additional investment required).[24] Some costs could fall to taxpayers, for example upfront costs or costs that feed through to the housing benefit bill.

### Owner-occupiers

4.29 Some owner-occupiers may choose to pay for improvements up-front, while others may take out a loan, or take out or add to a mortgage. There are a growing number of green mortgages available, and the government has been engaging with lenders, their engagement organisations, and other financial stakeholders to understand how government can encourage lenders to innovate further in this area. This may not be an option for all households, for example, households which already have a high loan-to-value mortgage or live in regions with lower average property values. The government currently has a range of schemes in place to support homeowners with the costs of improving energy efficiency and reducing their emissions from heating, in particular households are least able to pay, and live in the worst performing dwellings. Further details are set out in the Heat and Buildings Strategy.

4.30 There is some correlation between exposure to the heat and building transition and housing wealth. In order to understand this in greater detail, Chart 4.F

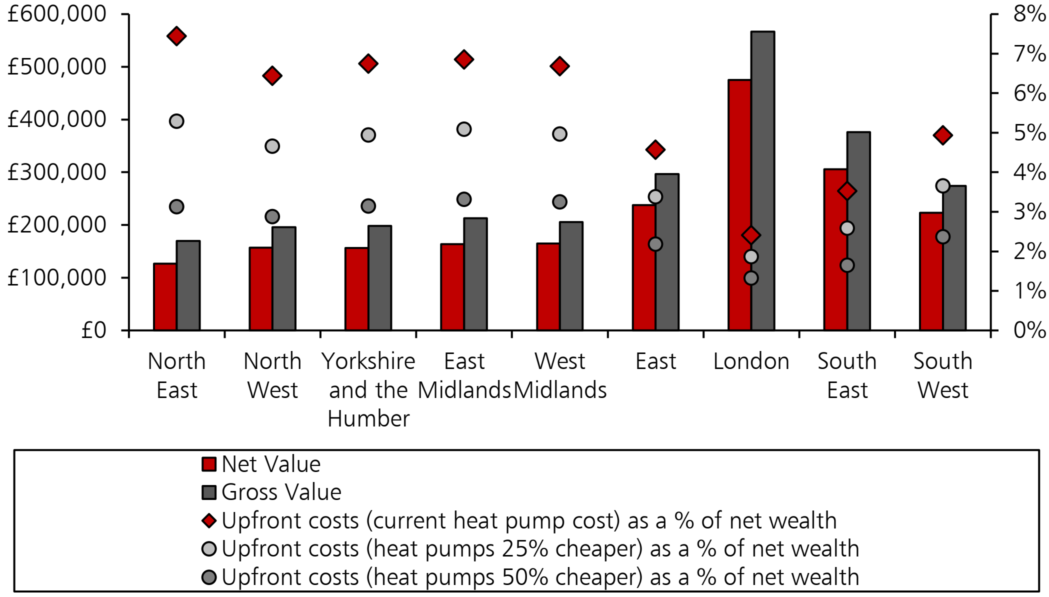
[22] 'Determining the costs of insulating non-standard cavity walls and lofts', Energy Saving Trust, 2019.

[23] 'Planning responsible retrofit of traditional buildings', Neil May and Nigel Griffiths, Sustainable Traditional Buildings Alliance, July 2015.

[24] HMT analysis of 2016-18 England Housing Surveys and 2017 Fuel Poverty dataset.

considers average investment in improvements as a proportion of net housing wealth (net of mortgage wealth), broken down by region. Given the likely fall in heat pump costs Chart 4.F illustrates a range of scenarios. This is lowest in London and the South East, but above 7% on average in some regions. These averages will mask variations. For some owners, the costs could represent a significant proportion of housing wealth. This chart also illustrates the impact that lower heat pump costs could have on housing decarbonisation costs, as per Chart 4.E.

### Chart 4.F: Net and gross housing wealth (among owners) by region in England, and comparison to average investment in improvements




*Source: HM Treasury calculations*[25]

4.31 Improvements could have an impact on house prices, although the exact scale and timing of impacts will depend on housing market dynamics and future policy.

## Decarbonising domestic buildings could impact energy bills

4.32 Decarbonisation has implications for household energy bills, as discussed earlier in this chapter. While investing in energy efficiency measures will lead to lower energy bills, these reductions might not offset higher running costs for households which switch from gas heating to electric heat pumps. This is because current unit prices of electricity are significantly higher than equivalent gas prices, leading to higher bills overall, despite heat pumps being more efficient. Addressing the imbalance between gas and electricity prices will be important in reducing this price differential in the future, helping heat pumps become an increasingly attractive consumer proposition and helping to remove a critical barrier to heat pump deployment. The Heat and Buildings Strategy confirms that the government would like to reduce electricity costs so, when the current gas spike subsides, it will look at options to shift or rebalance energy levies and obligations away from electricity to gas over this

[25] HM Treasury analysis of Wealth and Assets Survey.

decade. This will include looking at options to expand carbon pricing and remove costs from electricity bills while limiting any impact on bills overall. The government will launch a Fairness and Affordability Call for Evidence to help rebalance electricity and gas prices and to support green choices, with a view to taking decisions in 2022.

4.33 However, as for other areas of the heat and buildings transition, any energy bill impacts will not be felt equally across households. Some households could see immediate reductions in their energy bills, in particular households currently off the gas grid and those currently using direct electric heating. Households living in high-rise flats are also likely to benefit from lower bills. These factors are likely to be more important in predicting a household's exposure to bill changes than their income level.

# Electric vehicles

## Overview

4.34 In 2019, surface transport in the UK is expected to have produced 112 MtCO2e of carbon, representing 25% of the UK's carbon emissions.[26] Decarbonising this sector is one of the main ways in which some households will be affected by the transition to net zero. Nearly all of these emissions currently come from internal combustion engine (ICE) vehicles.

4.35 The government has committed to ending the sale of new petrol and diesel cars and vans in 2030, with all new cars and vans sold after 2035 to be fully zero emission at the tailpipe. This commitment applies only to the sale of new ICE cars and vans, so the impact on households will be gradual as there will still be ICE cars and vans available in the second-hand market. As a result, the 30 million ICE cars currently owned by households will be replaced by zero emission alternatives.[27]

4.36 There is significant uncertainty over the model of car use and ownership in the future, which will affect the degree to which motorists are exposed to the transition. While there has been increased car usage in aggregate,[28] Chart 4.G shows that this masks variations in car use by income; higher income households have a declining rate of car use for journeys, offset by an increase in car use by lower income households. It is challenging to predict behavioural and technological changes over the 30-year transition. However, public transport use or technology-driven car sharing capacity may reduce the need for car ownership or usage for some households. This is likely to be particularly true for infrequent car users or those well served by improved transport links.

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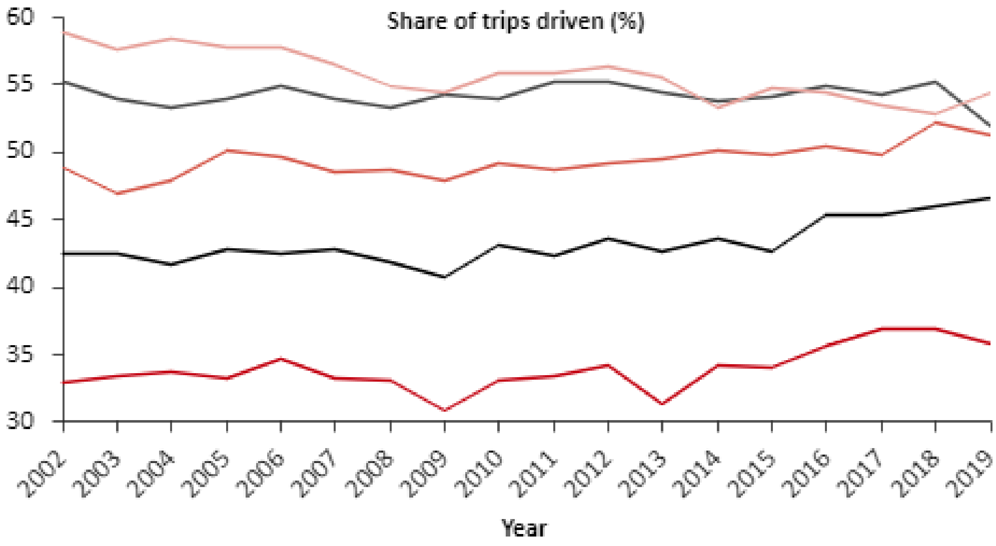
[26] Final UK greenhouse gas emissions national statistics, BEIS, February 2021.

[27] Vehicle Licensing statistics, Cars (VEH02), DfT, 2021.

[28] 'Road traffic statistics, summary statistics', DfT, 2021.

## Chart 4.G: Proportion of all trips that were driven by income quintile




*Source: HM Treasury calculations*[29]

## Factors that affect the cost of buying and running an EV

4.37 The total cost of ownership of an EV (including upfront and running costs), relative to an equivalent ICE vehicle, will depend on future government policy and a variety of other factors, including:

- the price of the vehicle;
- access to finance;
- variation in usage;
- maintenance costs; and,
- cost of charging.

### Price parity

4.38 Currently, the upfront cost of an EV is higher than for an ICE equivalent, but the costs of fuel and maintenance are lower. As battery technology improves and the production of EVs increases, the upfront costs are expected to fall. Bloomberg New Energy Finance (BNEF) project falls in the upfront costs in the 2020s.[30]

4.39 The production of EVs is a new and expanding market and the long-run projection of costs is highly uncertain. Notably, current estimates focus on price parity for a typical vehicle. However, households do not all purchase the

[29] HM Treasury analysis of National Travel Survey.

[30] 'Electric Vehicle Outlook 2020', Bloomberg NEF, 2020.

typical vehicle. The determinant of whether any household is better or worse off as a result of the transition to EVs is therefore whether there is total cost of ownership price parity between the type of vehicle they currently buy and their EV replacement.

4.40 Many households, and disproportionately lower income households, purchase cars on the second-hand car market. Understanding how prices on the second-hand EV market will evolve is even more challenging, given that it is a new market. One factor that will be important in determining the pricing of new and second-hand EVs is their depreciation rate. Information exists for the price and range deterioration of old EVs, but there is rapid technological development in this sector, and future cars may depreciate or deteriorate differently. For example, battery quality and range has already significantly improved compared to early EV models. However, given the immaturity and consequent volatility of the second-hand market, it is currently difficult to draw conclusions on this.

## Access to finance

4.41 There is already an efficient finance market for the purchase of new cars with around 90% of new cars purchased on finance.[31] However, only around 20% of second-hand cars are purchased using finance.[32] This difference may partially reflect demand for finance; the average price of a second-hand car is lower than a new car, so it is less likely finance is required, and people are more likely to use savings or cash to buy cars outright. However, it may also reflect the support manufacturers provide in offering finance, the availability of finance options, or eligibility for finance. Notably, interest rates in second-hand car finance arrangements are typically significantly higher than for new car purchases. If the upfront cost of second-hand EVs remains higher than the price of second-hand ICE vehicles today (either due to slower depreciation, residual value of the battery, or any other reason), then access to finance may become increasingly important in order to support decarbonisation of surface transport.

## Variation in usage

4.42 The higher upfront cost and lower running costs of EVs relative to ICEs mean that individuals who use their cars more often will reach price parity between the two types of vehicle sooner. This means they will face smaller net costs (or greater net benefits) from the transition to EVs, while infrequent users will face higher costs (or fewer benefits).

## Maintenance costs

4.43 EVs generally have lower maintenance costs than ICE vehicles. This could represent a saving to all households who own a car.

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[31] 'Latest Motor Finance Statistics', Finance and Leasing Association, 2021.

[32] In 2018, 1.5m used car purchases were made using finance out of a total of 7.9m. 'Car Finance report, 2018', The Car Expert, 2018; Used Car Sales, Statista 2019.

## Cost of charging

4.44 The UK is at an early stage of the EV transition, and the development of the charging network over the next thirty years will be important in determining how the costs of charging eventually affect households.

4.45 Private investment in the UK charging market is rapidly increasing. While the private sector leads on the development of the charging network, the government currently intervenes where there are market failures to ensure there is a core charging network ahead of need. At present, the upfront cost of grid upgrades is a barrier to the rollout of a charging network on the Strategic Road Network to support long journeys. To help address this, the government has committed £950 million to futureproof grid capacity to enable the private sector to rollout rapid charging hubs at motorway service areas and key A-Road service areas.

4.46 Unlike refuelling a petrol or diesel car, there are different options for charging an EV. How drivers choose to charge their vehicle and the charging that is available will influence the costs and benefits of EV adoption. Looking ahead, there are at least two major sources of uncertainty in this area to account for:

- **Charging segments, behaviour and technology**. There are a range of ways to charge: off-street charging; on-street charging, using lamp posts chargers or free-standing pillars; destination charging at workplaces or shopping centres; and, rapid charging hubs at petrol forecourts. These will vary in cost, but the degree to which the costs vary will be dependent on technological change and the variable cost of electricity, as well as potentially the ability to substitute batteries instead of relying on rapid charging; and,

- **Variable electricity prices**. Currently, overnight at-home charging enables households to make use of cheaper off-peak energy prices. Shifting charging away from peak times can significantly reduce costs by avoiding the need for network reinforcement and additional generating capacity. In addition, technologies such as Vehicle-to-Grid have the potential to provide additional flexibility in the energy system. Smart charging, through a wide range of smart electricity tariffs, smart charging devices and related services, will provide additional support to EV owners.

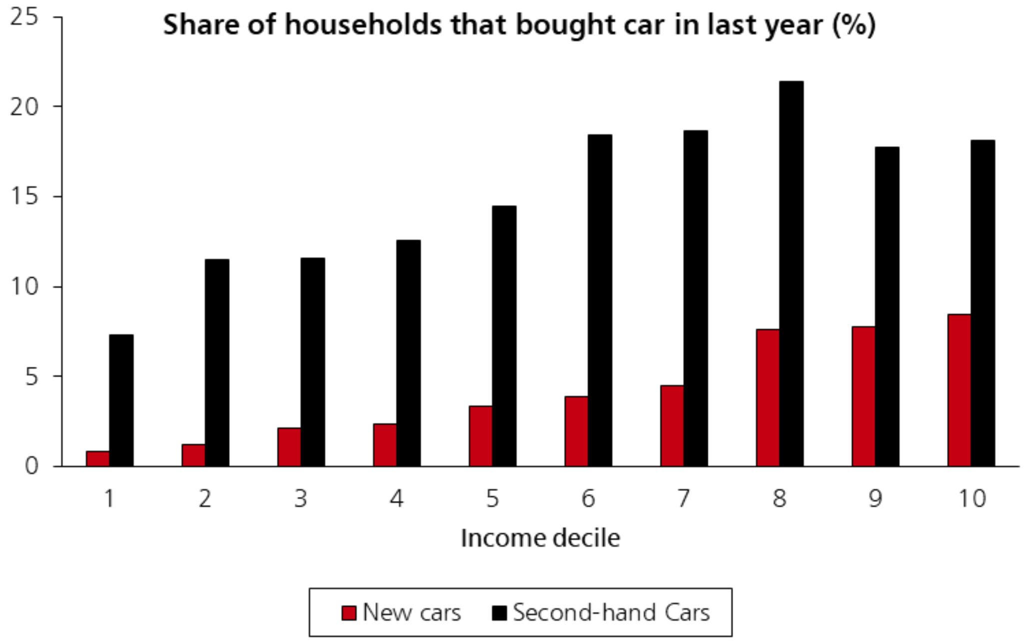
# Different households will be exposed to the EVs transition at different points in time, and household characteristics affect how soon benefits are realised

## Higher income households are likely to transition to EVs sooner

4.47 It is challenging to forecast EV ownership over a 30-year period. However, it is possible to consider past trends to understand when households might transition to EVs. For the purposes of the analysis below, it is assumed that rates of car ownership remain the same over the net zero transition.

4.48 Higher income households are more likely to buy new vehicles, and so take up EVs sooner. Low-income households are likely to be the slowest to adopt EVs as they are the least likely to purchase new cars. As shown in Chart 4.H, 90% of car purchases in the lowest income decile are on the second-hand car market, compared to 70% of purchases in the highest income decile. The probable faster adoption of EVs by higher income households means that policies to support the adoption of EVs may disproportionately benefit higher income groups. This could create a trade-off in some areas between incentivising decarbonisation and minimising adverse distributional impacts.

### Chart 4.H: Proportion of households that bought a new or second-hand car in the past year




*Source: HM Treasury calculations*[33]

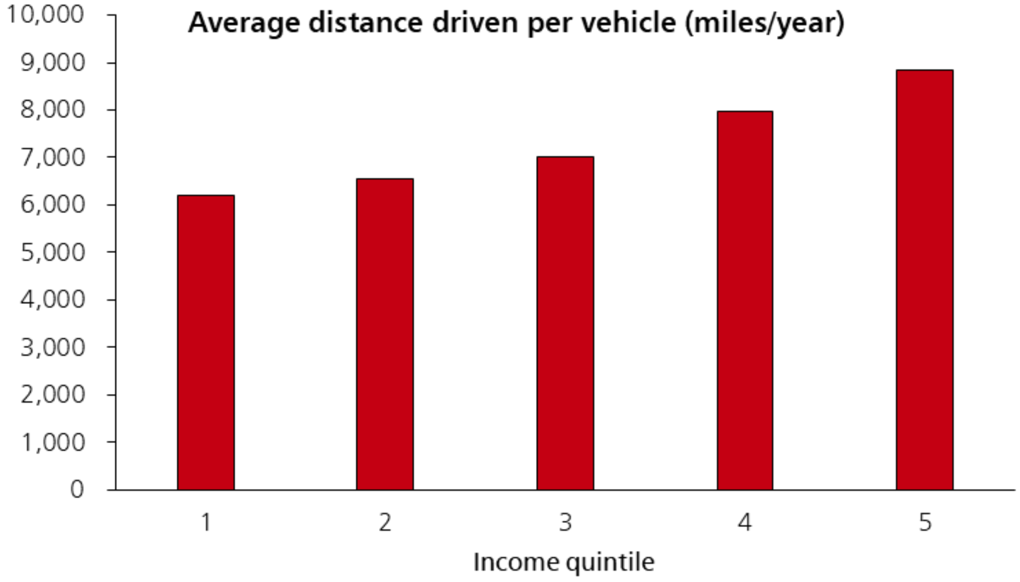
4.49 While those in higher income groups are more likely to be early adopters, and consequently take on higher costs, it will also be important to consider the costs of running ICE vehicles as they decline in usage and more drivers adopt EVs. As ICE ownership declines, the availability and price of petrol and diesel refuelling is likely to change. These changes – assuming all else being equal – are likely to be disproportionately felt by lower income households as well as those who choose to delay switching to EVs voluntarily. This could create a trade-off between incentivising decarbonisation and minimising adverse distributional impacts.

## Car usage varies by geography, income and age, which will influence how soon the benefits of the EV transition could be experienced

4.50 Car usage is a key factor in determining how soon savings may accrue to households. Different factors affect car usage which influence how soon the benefits will be experienced. As shown in Chart 4.I, higher income households have an annual mileage per vehicle of almost 9,000 miles compared to just over 6,000 miles per year among the lowest income households. This implies that – even when purchasing the same vehicles – price parity will be achieved earlier for higher income households.

[33] HM Treasury analysis of Living Costs and Food Survey.

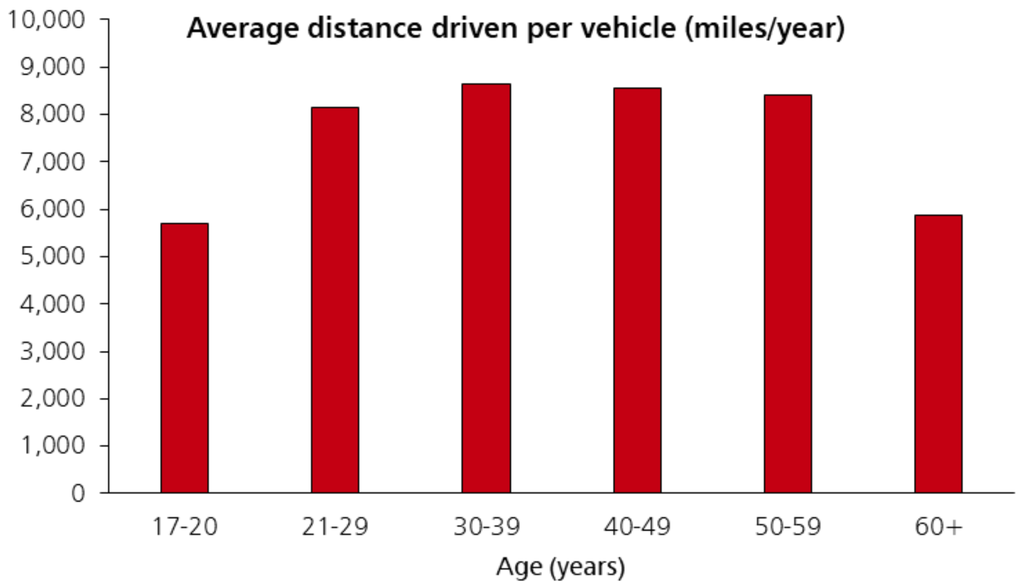
### Chart 4.I: Annual mileage per vehicle by income quintile in 2019




*Source: HM Treasury calculations*[34]

4.51 This dynamic would also apply to very young drivers and those over the age of 60, as they typically drive fewer miles than the average driver.

### Chart 4.J: Annual mileage per vehicle by age in 2019




*Source: HM Treasury calculations*[35]

34 HM Treasury analysis of National Travel Survey.

35 HM Treasury analysis of National Travel Survey.

# Chapter 5

# A low-cost transition

The transition to a clean economy is being driven by a clear commitment, enshrined in law, to achieve net zero by 2050. This is in contrast to previous economic transitions, such as those driven by technological change, globalisation or digitisation. It provides an opportunity to plan ahead and design policies to keep costs as low as possible, maximise the benefits for the economy, and to manage the distributional consequences.

Multiple policy instruments will be needed to address multiple market failures. Competitive markets are likely to deliver the most efficient transition across the economy. They are best supported by a broad-based carbon pricing policy, much like government has with the UK Emissions Trading Scheme (UK ETS), which can incentivise decarbonisation and green innovation if emissions are appropriately priced. This gives the private sector the flexibility to decide how to decarbonise most effectively and to do it at minimal cost, which will help to ensure that households – to whom costs ultimately pass through – are not burdened with unnecessary costs.

In addition to a carbon price system, further complementary policy will be needed to create the right incentives. Well targeted and designed regulation will continue to have a central role in reducing emissions and can be an effective tool where demand is not responsive to changes in price. It can also benefit consumers through more efficient products and standards. Public spending could support an increase in private investment, as highlighted in the Ten Point Plan. Together, these levers will help to support the transition to net zero and a green economy.

There will be significant technological uncertainty during the 30-year transition. Innovation will be essential over the coming decade. Policy can help the private sector to overcome risks in technological development and maintain the pace of decarbonisation. The balance between increasing technology optionality and reducing the risk of stranded assets will be important in maximising benefits and minimising costs.

## Overview

5.1 An economically efficient transition would seek to address directly the market failures preventing decarbonisation, primarily the negative externality from emitting greenhouse gases; provide clear signals to the private sector to encourage green investment and innovation; limit the risk of government failure; and avoid costly and sub-optimal technology lock-ins.

5.2 Multiple policy instruments will be needed to address multiple market failures, which will vary for different technology transitions. The government has a range of policy levers available to support decarbonisation[1]:

- Carbon pricing levers or other tax levers that increase the cost of emissions and so incentivise action to reduce emissions and increase investment in lower carbon technologies;
- Regulations that compel action to decarbonise; and,
- Taxpayer support that incentivises or directly funds decarbonisation.

5.3 The choice of policy levers comes with trade-offs. In choosing policy, the government will need to consider factors such as how costs are distributed, any risks from carbon leakage, and new trading opportunities.

5.4 It will also be important for government to provide clear, credible and consistent public direction. This will reduce uncertainty, provide a more favourable environment for investment in net zero technologies, and help households and businesses optimise their investment decisions. The government can support this through policy clarity for its climate targets – for example, timely signals such as technology phase-out dates, carbon pricing, taxonomies that define sustainable economic activities, and transparent decision-making when choosing between technologies.

## Carbon pricing can support the reorientation of the economy in an efficient way

### The role of carbon pricing in driving the transition

5.5 Carbon pricing directly addresses the core market failure driving climate change: that firms and households do not always face a cost to reflect the impact their actions have on the climate from emitting greenhouse gases.

5.6 Widespread carbon pricing can apply a consistent incentive across all sectors of the economy, allowing the private sector to decide how to decarbonise most efficiently across sectors, and to do it at minimal cost. The IMF has said that carbon pricing is "the most powerful and efficient [lever], because it allows firms and households to find the lowest-cost ways of reducing energy use and shifting toward cleaner alternatives".[2] Carbon pricing achieves this by incentivising firms and consumers to switch away from high carbon options without prescribing a specific low carbon alternative, allowing competitive firms to innovate and reduce costs with new options.

5.7 In comparison, regulation and public spending schemes typically require government to design each intervention specifically for each sector and, due

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1 There are also levers that will help facilitate the transition to net zero such as improved information, skills programmes, new financial products, intellectual property policy and international climate agreements.

2 'How to Mitigate Climate Change', IMF, 2019.

to potential government failure, carry a risk of imperfect information increases consumer costs or leads to other market inefficiencies.

5.8 Carbon prices also send clear long-term signals and incentives to private investors and households, stimulating investment, demand and innovation in green technologies. This effect is driven by the generally positive relationship found in econometric studies between demand-pull policies such as carbon pricing and innovation across numerous sectors including industry, electricity and transport. Innovation is then found to lead to technology costs falling and more investment being channelled into green alternatives as they become increasingly competitive, leading to further emission reductions.[3] This makes carbon pricing well suited to deliver a significant proportion of the emission reductions required to meet the net zero target in 2050, which is consistent with the position of both the IMF and OECD.[4] Other levers can also be effective at driving innovation and energy efficiency gains.

5.9 The earlier the carbon price signal to the market, the better for inducing green technological innovation and efficient decarbonisation. This is because consumer behaviour is likely to be less responsive to carbon pricing where low-cost, green technologies are limited. However, this changes as the carbon price signals spur innovation and technology choices improve. UK and international studies assessing the price elasticity of demand for high carbon goods across different sectors of the economy have found that demand is more inelastic in the short-run than in the long-run, as shown in Chart 5.A.[5]

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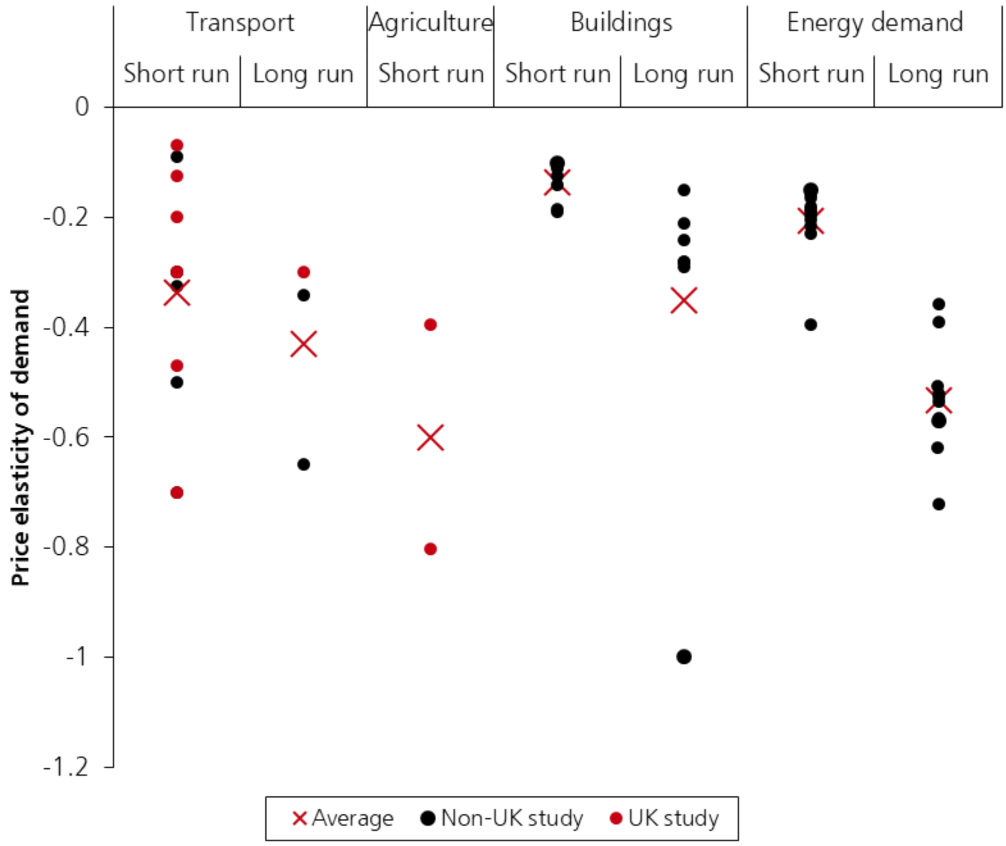
3 'Induced innovation in energy technologies and systems: a review of evidence and potential implications for CO2 mitigation', Grubb et al., 2021.

4 'Effective Carbon Rates: Pricing CO2 through Taxes and Emissions Trading Systems', Organisation for Economic Cooperation and Development (OECD), 2016.

5 Half of the studies are UK based with the other half outside of the UK, affecting the external validity of the evidence. Studies are also based on retrospective evidence, which does not factor in the greater availability of substitutes for consumers in the future. For further details, see Annex A.

## Chart 5.A: Short-run and long-run price elasticities by sector




*Source: HM Treasury calculations*

## Economic impacts of carbon pricing

5.10 Studies suggest that the impact of carbon pricing on GDP has been small.[6] These studies tend to measure the impact of carbon pricing on GDP retrospectively, relative to a no climate action and a no climate change counterfactual.

5.11 Assessing the macroeconomic impact of carbon pricing to 2050 is more challenging, as outlined in Box 5.A. However, several estimates suggest that carbon pricing expansion and long-term economic growth could be compatible.

### Box 5.A: Estimates of the macroeconomic impact of carbon pricing to 2050

Attempts to assess the impact of carbon pricing out to 2050 require assumptions to be made on key elements, such as the effect of revenue recycling on consumption and growth, or the risk and effect of businesses relocating to countries with less stringent pricing regulations.

[6] Metcalf and Stock consider carbon pricing in Europe to estimate its impact on GDP and employment, finding no robust evidence of a negative effect of the tax on employment or GDP growth. 'Measuring the Macroeconomic Impact of Carbon Taxes', Metcalf and Stock, 2020.

Montenegro et al. use a recursive-dynamic multi-regional Computable General Equilibrium model to represent carbon pricing as a cap-and-trade system and calculate its impacts on various macroeconomic indicators. They find positive economic growth across a range of EU ETS scenarios with varying sectoral coverage, level of ambition and international cooperation until 2050. The methodology used perceives the gains and losses of any policy measure solely as a matter of profit and cost, therefore excluding consideration of the economic benefits of mitigated climate change.[7]

An IMF study uses G-Cubed model simulations to measure the impact of the phased-in carbon price increase with the assumption of compensatory transfers (revenue recycling of about 25% of the tax) within the policy package. The study finds a carbon tax to have a negative impact on global real GDP of around -4.5% (within the context of 120% global GDP growth over thirty years) but also finds that carbon tax has a substantial positive fiscal impact that can contribute to financing other policy measures, such as investment. The study includes the economic benefits from avoiding climate change, but these only materialise rapidly after 2050, meaning their assessment of carbon pricing between 2020 and 2050 is at most marginally influenced by improved climate outcomes.[8]

5.12 IMF research illustrates the relatively low mitigation cost of using carbon pricing. The IMF estimates that the mitigation costs of alternative policy levers, such as feebates with regulation, could be 50% to 100% higher for the same emissions reduction than using carbon pricing.[9] A mix of policy levers across tax, spend and regulation will be used by government during the transition, to set frameworks and send long-term signals to the private sector.

## Mechanisms for carbon pricing: carbon taxes and emissions trading

5.13 There are two main mechanisms for imposing an explicit price on carbon emissions in the UK: a direct tax levied at a given value against a quantity of emissions; and emissions trading, where limits may be set on emissions (also known as 'cap and trade').

5.14 Under a cap-and-trade scheme, the government sets an overall cap on carbon emissions for a given time period. The cap dictates how many tonnes of carbon can be emitted in a given year. Firms must buy allowances equivalent to their emissions for that year. This gives firms an incentive to reduce emissions so that they have to buy fewer allowances and can sell any surplus.

5.15 The limit on supply provided by the cap, set to a predictable, long-term and decreasing trajectory, drives behaviour both through the current allowance price, and through expectations of future prices given the announced reduction in future allowance supply.

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[7] 'Long-Term Distributional Impacts of European Cap-and-Trade Climate Policies: A CGE Multi-Regional Analysis', Montenegro et. al. 2019.

[8] 'Mitigating climate change – growth and distribution friendly strategies', IMF, 2020.

[9] 'How to mitigate climate change', IMF, 2019.

5.16 In theory it is more economically efficient to use a single mechanism – taxation or emissions trading – across sectors, though there may be practical reasons why a different mechanism may be more appropriate in some sectors.

## International trends and successes

5.17 Globally there has been increasing emphasis on carbon pricing as a key policy tool for reducing carbon emissions. As of May 2020, there were 61 carbon pricing initiatives implemented or planned around the world, of which 31 were emissions trading schemes and 30 were carbon taxes, across 46 national and 32 subnational jurisdictions and covering around 22% of global greenhouse gas emissions. Table 5.A provides a comparison of international examples of carbon pricing mechanisms.

### Table 5.A: Comparison of sectoral coverage of carbon pricing mechanisms

| Jurisdiction | Power | Industry | Aviation | Transport | Heating | Waste | Agriculture & Forestry | Shipping | % of GHG emissions covered |
|---|---|---|---|---|---|---|---|---|---|
| New Zealand | X | X | X | X | X | X | X | | 51% not including agriculture |
| EU ETS (EU Commission proposal) | X | X | X | X | X | | | X | Up to c.85% |
| South Korea | X | X | X | | X | X | X | | 70% |
| Chinese pilot schemes | X | X | X | X | X | | | X | 40-60% |
| Germany | X | X | X | X | X | | | | c.40% + EU ETS |
| Sweden | X | X | X | X | X | | | | c.40% + EU ETS |
| France | X | X | X | X | X | | X | | c.30% + EU ETS |
| Quebec | X | X | | X | X | X | X | | 82% |
| California | X | X | | X | X | | | | 80% |
| Canada Federal System | X | X | X | X | X | | | | Varies by province |
| EU ETS | X | X | X | | | | | | 45% across EU |
| UK (at present) | X | X | X | | | | | | c.33% |
| Switzerland | X | X | | | | | | | 10% |
| Kazakhstan | X | X | | | | | | | 50% |
| Mexico | X | X | | | | | | | 37% |
| Chinese national scheme | X | | | | | | | | c.40% |
| Tokyo & Saitama, Japan | | X | | | | | | | 38% |
| Regional Greenhouse Gas Initiative (RGGI) US | X | | | | | | | | 18% |

*Source: World Bank, HM Treasury and BEIS estimates*

5.18 Key global climate partners and major emitters are taking steps to expand carbon pricing, in an effort to make credible strides towards net zero. Although the UK has had a strong track record on carbon pricing, the table above shows that the UK still has progress to make in terms of the proportion of greenhouse gas emissions that these schemes cover. This year, China has introduced a national ETS. In July 2021, the EU published proposals to strengthen carbon pricing in the EU. This includes a revision of the EU ETS, including an extension to shipping, a revision of the rules for aviation emissions and the phasing out of free aviation emissions allowances, as well as establishing a separate emissions trading system for road transport and buildings. Canada's Supreme Court has recently ruled in favour of a Federal Carbon Tax for those provinces that have not adopted a mechanism. New Zealand has a carbon pricing mechanism that already covers most sectors of the economy and the government has announced plans to expand this to agricultural emissions from 2025. South Africa recently became the first country in Africa to put a price on carbon.

## UK approach to carbon pricing

5.19 The UK's primary carbon pricing mechanism is the UK ETS (see Box 5.B), which covers around a third of the UK's territorial emissions. Delivering on the net zero target requires credible policy commitments, including on carbon pricing. The government has committed to implement a net zero-consistent trajectory for the annual cap on emissions covered by the scheme, and to enshrine this in law. In addition, the UK has committed to explore expanding the UK ETS to sectors that are not already subject to an explicit carbon price, in order to ensure that emissions are reduced across the economy in line with our obligations.

5.20 Scaling our carbon pricing mechanism to deliver on our own decarbonisation commitments will not only support the transition, but also generate additional revenue which could be used to offset additional public investment in decarbonisation.

### Box 5.B: Carbon pricing across the UK

The UK is a pioneer in developing emissions trading policy, first independently in 2002 and then as part of the EU ETS. Outside the EU, the UK is seeking to innovate and develop a UK ETS as a key lever to help reach net zero by 2050, the 2030 Nationally Determined Contribution, and Carbon Budget targets.

The UK ETS is a joint scheme between the UK government and the devolved administrations (DAs) who work together as one UK ETS Authority. The UK ETS currently applies to energy-intensive industries, electricity generation, and aviation (domestic, UK-EEA and Gibraltar). This equates to roughly one third of UK territorial emissions. Auctions commenced in May 2021.

Under the Northern Ireland Protocol, Northern Ireland power generators have remained in the EU ETS as part of the Single Electricity Market on the Island of

Ireland. Northern Ireland energy intensive industries and aviation are covered by the UK ETS.

The government has committed to consult on the implementation of a net zero consistent cap trajectory to 2050.

In addition to this, the government is open to linking the UK ETS internationally in principle and is considering a range of options, but no decision on any preferred linking partners has yet been made.

The Government also committed in the Energy White Paper to explore expanding the UK ETS to additional sectors, including considering how the UK ETS could incentivise the deployment of greenhouse gas removal technologies. A market-based solution for removals could help the development and deployment of these technologies, which will be required at scale if the UK is to meet its net zero target and offset emissions from hard-to-abate sectors such as aviation and industry.

The UK also has a carbon tax, the Carbon Price Support. It is levied at £18 per tonne on emissions from power generation, providing a further incentive for decarbonisation. The Carbon Price Support has, in concert with Contracts for Difference, significantly shifted the economics of and investment incentives for renewables compared to coal for domestic power generation. Coal consumption has declined 84% in 10 years.[10]

## Carbon pricing on its own will not decarbonise all sectors

5.21 Carbon pricing is a necessary and powerful tool for delivering widespread and cost-effective emission reductions. Carbon prices directly address the main climate change market failure, allow firms flexibility in choosing how to abate, and thereby potentially lower the overall cost of abatement. However, well-designed alternative policy tools will be required to overcome other specific barriers to decarbonisation, such as inertia, financing, economies of scale, or coordination failures. It will therefore be essential to support carbon pricing with regulation and other policy levers that can make markets work better and deliver emission reductions across the economy. When well-designed these measures can support a cost-effective transition and economic growth, but also carry the risk of adverse economic consequences where they force too rapid an adjustment, focus on sub-optimal technologies or create perverse market distortions.

### Additional price incentives can catalyse a change in behaviour

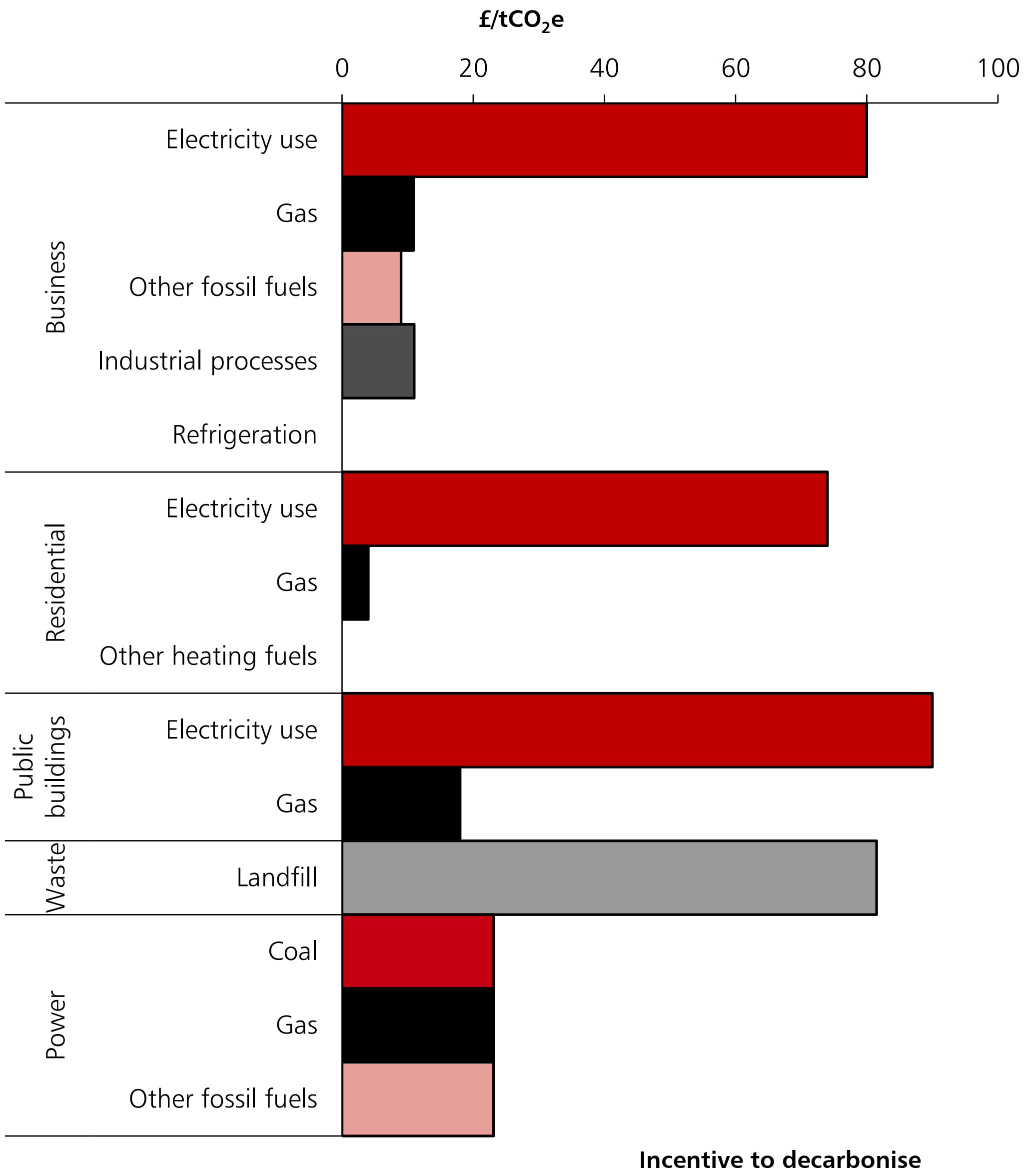
5.22 Government policy can create price incentives for decarbonisation, in addition to direct carbon pricing. Some of these price incentives are designed explicitly

[10] 'Coal consumption and coal stocks', BEIS, 2021.

for decarbonisation; others target other policy objectives but have implications for decarbonisation policy. This results in both explicit and implicit carbon price signals across the economy.

5.23 By understanding these price incentives across the economy, the government can identify where there are incentives or disincentives to decarbonise. Chart 5.B presents a view on the price incentives across different sources of carbon and other greenhouse gas emissions. For example, in residential energy consumption, the price signals placed on different sources of energy may provide a weaker incentive to use electricity rather than gas, which is relatively under-priced. Given that natural gas is more carbon intensive than electricity, this may incentivise households to choose more polluting fuels over the lower carbon alternatives. The government will launch a Fairness and Affordability Call for Evidence to help rebalance electricity and gas prices, with a view to taking a decision in 2022.

## Chart 5.B: Carbon price incentives




*Source: HM Treasury calculations*[11]

5.24 The government will need to balance different objectives in designing policy, and in some areas these objectives may provide price signals in different directions. For example, policy will need to balance the objectives of competitiveness and decarbonisation when providing free allowances under the UK ETS.

## Regulations will continue to play a central role in reducing emissions

5.25 Regulations have been an effective tool in delivering UK emission reductions to date. Box 5.C provides an example of this. They can be an effective tool to compel a shift in consumer behaviours and production processes, for example where demand is not responsive to changes in price. Where these regulations have compelled a change to new, more efficient products and standards,

[11] 'Current Economic Signals for Decarbonisation in the UK', Oxford Energy Associates, 2017. Updated by HM Treasury.

consumers have also benefited from lower operating costs over time. The CCC estimate that energy efficiency regulations on boilers and household appliances have saved households £290 on their annual energy bill between 2008 and 2017.[12]

5.26 Clearly-signalled, highly-targeted and well-designed regulatory policy can provide households and businesses with certainty and confidence to make the right investment and consumption decisions at the right time. This can support innovation and capital mobilisation, as investors have the certainty they need to plan and invest for the future. In turn, this can lower the cost of capital and boost efficiency and productivity.

5.27 In designing regulations, it will be important to bear in mind:

- Insufficient time between the announcement of a new regulation and the implementation date can create high adjustment costs and may increase stranded assets. For example, if new capital investment is required outside of replacement cycles, this can lead to a loss as productive assets are written off;
- Delaying the announcement of regulation could also increase the overall cost of the transition, as the stringency of regulation increases in order to meet emission abatement targets across a shorter period of time.[13] However, if costs were to fall substantially towards the tail-end of the transition, this may no longer be the case; and,
- Poorly designed regulations can impose restrictions on innovative economic activity and reduce economic efficiency. This is a particular risk where regulations are excessively technology-specific or anti-competitive.

5.28 A further way government can increase market confidence, and support investment in innovation, is through predictable and transparent energy network regulation. In the National Infrastructure Strategy, [14] the government supported the National Infrastructure Commission's conclusion that the framework for economic regulation needs updating to ensure it can rise to the challenges of the 21st century, including the need to decarbonise infrastructure across all networks. The government will publish further detail this year to facilitate future investment needs, increase innovation, and meet the needs of both current and future consumers.

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12 'Energy prices and bills report 2017', Committee on Climate Change, 2017.

13 'Climate Change Scenarios – Implications for Strategic Asset Allocation', Vivid Economics, 2011.

14 National Infrastructure Strategy, HMT, 2020.

## Box 5.C: Introduction of energy labelling and minimum energy performance standards (MEPS)

The UK introduction of energy labelling and minimum energy performance standards for cold appliances in 1994 and 1999 led to cost-effective energy savings.[15]

Analysis in 2007 suggested efficiency savings in the UK equated to over 2 TWh in 2006 compared to a base case without energy labels or MEPS.[16] An assessment by the European Commission highlighted how efficiency gains catalysed by MEPS led to economic benefits due to the energy capacity that could be redeployed elsewhere, growing the wider economy and increasing economic welfare.[17]

Among the factors that contributed to the effectiveness of these regulations were the four-year notice period between the announcement and implementation of the MEPS policy. This provided sufficient time for affected sectors to prepare for the change, allowing businesses to, for example, establish economies of scale in their supply chain to bring down production costs for new energy efficient products. It meant that the disruption to businesses at the point of implementation was relatively small.

The policy was also technology neutral. While the standards defined which products could be marketed and sold, the regulation gave autonomy to businesses to decide how they could best design products that complied with the standards in the most cost-effective manner, reducing the risk of significant additional production costs for businesses and higher prices for consumers.

The effectiveness of MEPS was complemented by the introduction of energy labelling for cold appliances, brought into effect five years earlier, in 1994.[18] This corrected for information failure, allowing consumers to make more informed choices and limiting search costs. This twin, market-pull approach, took the least efficient products off the market and enhanced consumer awareness in a non-obstructive manner, which allowed consumers and

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15 Commission Directive 94/2/EC of 21 January 1994 implementing Council Directive 92/75/EEC with regard to energy labelling of household electric refrigerators, freezers and their combinations, European Commission, (1994); Directive 96/57/EC of the European Parliament and of the Council of 3 September 1996 on energy efficiency requirements for household electric refrigerators, freezers and combinations thereof, European Commission (1996).

16 'Evaluating the impact of energy labelling and MEPS – a retrospective look at the case of refrigerators in the UK and Australia', Lane et al, 2007.

17 'Savings and benefits of global regulations for energy efficient products, European Commission', Molenbroak et al, 2015.

18 Commission Directive 94/2/EC of 21 January 1994 implementing Council Directive 92/75/EEC with regard to energy labelling of household electric refrigerators, freezers and their combinations, European Commission, 1994.

businesses to shape the market in a manner that was compatible with decarbonisation objectives.[19]

## Public spending can mobilise private investment

5.29 Some public investment will be required to support the role of carbon pricing and regulation. Policies such as those in the Ten Point Plan illustrate the role that government investment can play in catalysing wider private sector efforts for decarbonisation, where £12 billion of government investment could potentially mobilise three times as much from the private sector.[20]

5.30 Public spending should be focused in areas where the government has advantages over the market in delivering decarbonisation. This is likely to be in areas that are temporary and investments that are targeted, rather than supporting the ongoing consumption of goods and services which may result in additional emissions. Some examples include:

- investment in goods and services that the market cannot provide efficiently without government intervention, such as research related to decarbonisation;
- financial support where there is significant uncertainty for investors or barriers to entry and scale for new net zero technologies;
- coordination of market actors, for example to leverage further private finance for new large-scale infrastructure or lower the cost of capital; and,
- funding in the early stages of deployment to increase the affordability of technologies and move innovations along the technology adoption curve.

5.31 The government has announced initiatives in line with this, for example, supporting private investment in decarbonisation through the UK Infrastructure Bank, which is explained in more detail later in this chapter, and the Sovereign Green Bond, which is outlined in Chapter 6, Box 6.A.

5.32 In addition to domestic public investment, on 31 March 2021, the government ended financial and promotional support for fossil fuel overseas, and UK Export Finance (UKEF) is helping UK exporters in the fossil fuel sector to transition to clean activities through a new Transition Export Development Guarantee.[21]

[19] 'How effective are EU minimum energy performance standards and energy labels for cold appliances?', Schleich et al, 2020.

[20] 'The Ten Point Plan for a Green Industrial Revolution', 2020, HM Government.

[21] 'Aligning UK international support for the clean energy transition: government response', BEIS, 2021.

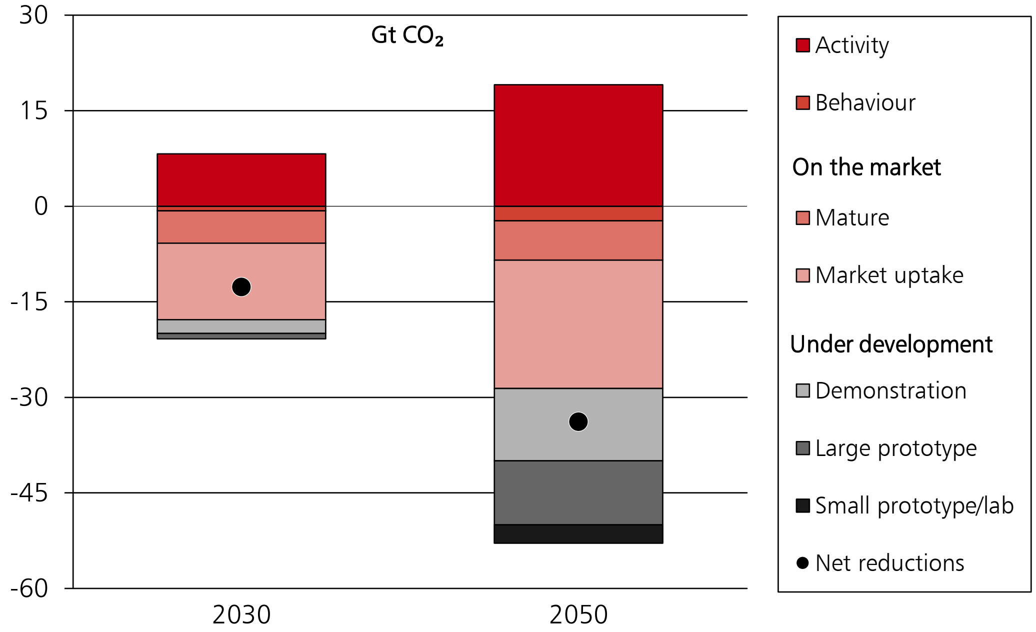
# Policy will need to navigate significant technological uncertainty

## Technological uncertainty

5.33 The transition to a net zero economy will see major changes in the technologies used across the economy and the power sources that fuel them. Many of the technological innovations needed to deliver net zero are being led in the UK. For example, Rolls-Royce is working on the world's largest jet engine which will cut aviation emissions, as part of their £500 million UltraFan engine project, and Jaguar will be all-electric from 2025

5.34 While many of the technologies that could support the UK's transition to net zero already exist, further technological developments will be important to ensure a cost-efficient transition. The International Energy Agency (IEA) notes that "reaching net zero by 2050 requires further rapid deployment of available technologies, as well as widespread use of technologies that are not on the market yet."[22] It estimates that in 2050 almost half of $CO_2$ emissions reductions will come from technologies currently at the demonstration or prototype stage, as shown in Chart 5.C. The precise mix of technologies that will be used in 2050 is difficult to predict. Therefore, it will be important to increase support for R&D and innovation in this decade and adopt a systems-approach over the coming decades.

### Chart 5.C: Global $CO_2$ emissions changes by technology maturity category in IEA Net Zero Emissions by 2050 Scenario




*Source: International Energy Agency*[23]

5.35 There are several technologies in the early stages of development that may prove to be game-changing technologies. For example, future long-term energy storage will be increasingly important as renewable sources generate

[22] 'Net Zero by 2050, A Roadmap for the Global Energy Sector', International Energy Agency (IEA), 2021.

[23] 'Net Zero By 2050: A Roadmap for the Global Energy Sector', IEA, 2021.

a larger share of electricity, but it is not yet clear which will be the most effective.[24]

5.36 There are also technologies where development will affect the shape and cost of the overall transition, such as greenhouse gas removal technologies (GGRs). More detail is provided in Box 5.D.

### Box 5.D: Case Study: Greenhouse Gas Removals (GGRs)

The CCC's Sixth Carbon Budget advice models 58 $MtCO_2$/year of greenhouse gas removals (GGRs) in 2050.[25] This includes 53Mt per annum of negative emissions from bioenergy with carbon capture and storage (BECCS) in 2050 and 5Mt from direct air carbon capture and storage (DACCS). These technologies are currently at the early stages of development, with one BECCS plant in pilot stage in UK. There is considerable uncertainty around the future costs of engineered GGR options and many technologies are not yet ready to be deployed at scale.[26] Estimates of the cost of these technologies vary. For DACCS, current cost estimates vary between US$250 to $600/ $tCO_2$ depending on the chosen technology and for BECCS between US$15 to $85/$tCO_2$.[27]

An understanding of the barriers to development and deployment of these technologies is key. The government issued a call for evidence in December 2020, and the response to this will be published later in 2021. In November 2020, the government launched a Direct Air Capture and other GGR Innovation Programme with the aim of investing up to £70 million in GGR innovation. This programme aims to increase understanding of these technologies, reduce costs and demonstrate the ability of these technologies at scale.[28] The National Infrastructure Commission was also commissioned to produce recommendations on GGR technologies, with their response and recommendations published in July 2021.[29]

## Policy can help the private sector to overcome risks in technological development and maintain the pace of decarbonisation

5.37 The scale of R&D and innovation required across the transition to net zero means that the private sector is well placed to seize the opportunities of the transition and lead the majority of the investment required. The private sector may hold expertise in specific sectors, which allows it to respond quickly to changes in the market, and assess the risks associated with investment in technologies effectively. There is also a deep pool of private capital available, which could be invested in net zero innovation if a supportive and predictable

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24 'The role of long-duration energy storage in deep decarbonization: policy considerations', World Resources Institute (WRI), September 2020.

25 The Sixth Carbon Budget report', CCC, 2020.

26 'Greenhouse Gas Removals: Call for Evidence', HM Government, 2020.

27 'Carbon Removal with CCS technologies', Global CCS Institute, 2021.

28 'Greenhouse Gas Removals: Call for Evidence', HM Government, 2020.

29 'Engineered greenhouse gas removals', National Infrastructure Commission (NIC), 2021.

investment environment is designed.[30] This is already happening. Private investment in the development and deployment of green technologies is already greater than public investment. For example, carmakers invested up to €47.7 billion to produce EVs in Europe in 2019.[31]

5.38 It is important to note that not all investment in technology will need to be made in the UK. Globally, a significant number of countries have committed to a net zero target and will require technological developments to reach this goal. As decarbonisation progresses across the world, there will be a global effort to innovate, spreading risk more widely and reducing the cost.

5.39 Risks and barriers to private investment will exist throughout the innovation cycle of emergent technologies. Some of these are outlined below in Table 5.B. During the early stages of development, the largest barriers come from technology risk, where there is a high risk of technology failure. Later-stage technologies can face market risks associated with their deployment and large-scale diffusion from uncertain market conditions and revenue streams. Policy risk can act as a barrier throughout a technology's lifecycle. The government can help the private sector to overcome these risks and drive technological development to achieve net zero.

## Table 5.B: Barriers to investment

| Barrier to investment | Explanation |
|---|---|
| Technology risk | Early-stage technologies face significant technological risk as there are high failure rates and predicting which inventions or innovations will work at scale is challenging. |
| Market risk | When technologies are introduced to the market there are still several barriers which can slow their deployment and commercialisation. For example, new technologies to the market are often not cost competitive and have uncertain revenue streams. Large-scale projects also face high capital costs. |
| Policy risk | Where there is a lack of clarity about regulatory or government policy, this creates uncertainty. |

5.40 Government support to the private sector's innovation efforts can take several forms. Some of these are outlined in Table 5.C, but generally focus on directly supporting innovation through funding scientific research and net zero R&D.

## Table 5.C: Government tools to support early-stage net zero innovation

[30] 'Unlocking capital for Net Zero infrastructure', PwC, 2020.

[31] 'Can Electric Cars beat the COVID crunch?', Transport and Environment, 2020.

| Tool | How does it support innovation? |
|---|---|
| Government grants | Government grants provide funding directly to businesses and research institutions to support specific areas of innovation activity, such as research into ground-breaking technology. |
| Prizes/ Competitions | Competitions provide cash incentives for innovators to work towards a defined goal. They can be harnessed to draw attention to specific innovation challenges for which there is a clearly defined outcome needed. |
| Challenge funds | Funds that are designed to address specific societal challenges, such as climate change. |
| Co-investment funds | Funds designed to enable investment from both the public and private sectors. Government is often the cornerstone investor, which can be matched, or more, by the private sector. The funds are managed and invested on a commercial basis by the private sector. |

5.41 Another way the government provides support is through innovation institutions and agencies. These channel government funding to businesses and researchers to drive innovation. UK Research and Innovation (UKRI) was launched in 2018 and has a combined budget of more than £6 billion for scientific research. It convenes seven research councils, Research England and Innovate UK to help deliver an ambitious research agenda.

5.42 As technologies are tested and proven, and technological uncertainty declines, technologies may still face challenges in being deployed at scale. While the private sector can lead the deployment and commercialisation of technologies, the government can play a role in minimising barriers. This is outlined further in Box 5.E.

### Box 5.E: Deployment and commercialisation of technologies

In some situations, the government may have a role to play in testing technologies at scale, where it may not be viable for the private sector to do so. For example, the government has allocated £240 million towards the Net Zero Hydrogen Fund in order to help develop up to 5GW of low carbon hydrogen capacity by 2030.

The government can also help overcome revenue risk where there is uncertainty around the ability for new projects to generate a reliable revenue stream. For example, the Contracts for Difference scheme was introduced to incentivise investment in renewable electricity generation, by providing a guaranteed market price, while maintaining competition in order to drive cost reductions for the benefit of the consumer. As set out in the Net Zero Strategy, the government is setting up the Industrial Decarbonisation and Hydrogen Revenue Support (IDHRS) scheme to fund new hydrogen and industrial carbon capture business models. This includes providing up to £100m to award contracts of up to 250MW of electrolytic hydrogen production capacity in 2023.

In addition, levies can fund revenue support for technologies such as offshore wind, onshore wind and solar power. Renewable electricity levies on consumer bills are forecast to be over £10 billion a year over the next four years across renewable electricity policy schemes (such as Contracts for Difference, the Renewables Obligation and Small-scale Feed-in Tariffs).

In some specific circumstances, when private investment is unable to bear the entire risk of a project, government support helps to share risk, for example by using the government's balance sheet to finance elements or guarantee loans for projects. Government-backed guarantees can help infrastructure projects access debt finance where they have been unable to raise funds in the financial markets. The UK Guarantees Scheme (UKGS) has issued £1.8 billion of guarantees over seven years[32] and supported private investment in nationally significant, large-scale UK infrastructure projects.

The UK Infrastructure Bank will provide leadership to the market in the development of new technologies, crowding-in private capital and managing risk through cornerstone investments and a range of financial tools. It will help to bolster the government's lending to local government for large and complex projects and to bring private and public sector stakeholders together to regenerate local areas and create new opportunities. The Bank will focus on intervening where it can make the biggest impact. This means addressing shortfalls in the provision of private finance to make projects happen that would otherwise not have had the necessary support.

5.43 For an illustration of how the government is supporting innovation to net zero at different levels of uncertainty, see Annex C.

## The balance between increasing technology optionality and reducing the risk of stranded assets will be important

5.44 As the transition progresses, consumers and markets will drive many of the decisions where there are choices between technologies and investment decisions required to meet net zero. However, in some sectors, there may be occasions where the government may need to take strategic decisions on technologies and decarbonisation pathways, for example, decarbonising

32 'Guidance: UK Guarantees Scheme', HM Treasury, 2017.

domestic heating. This is because there are network effects and coordination failures which mean that, without government intervention, the market may not choose the socially optimal or economically efficient decarbonisation pathway.

5.45 This presents a challenge for governments: there is significant uncertainty around which technologies will best support the transition to net zero in terms of cost, scalability and usability. For example, the reduction in the costs of electricity from offshore wind has been much steeper than predicted.[33][34] Backing an uncertain technology too soon could mean the economy is locked into an expensive and poor value for money technology pathway. There can therefore be value in maintaining optionality over a range of different early-stage technologies and adopting technology agnostic policy mechanisms. However, in some circumstances, decisions may need to be taken despite ongoing uncertainties in order to ensure deployment at sufficient scale by 2050.

5.46 Timescales for strategic decisions on technology pathways should consider the lifespans of current high carbon technologies in order to reduce the risk of stranded assets. Stranded assets result from a misalignment of market expectations of the returns on a high carbon asset and those actually realised as a result of climate policy, meaning that assets depreciate in value faster than the market expects. Where technologies have long asset lives, shifts away from high carbon technologies will need to happen much earlier than 2050 to avoid the risk of stranded assets. Appraisal of these investments should account for the costs that are likely to be incurred to offset these emissions or meet the liabilities under any future carbon pricing policies.

5.47 Carbon intensive firms and investors are the most exposed to the risk of stranded assets, and if managed poorly, the scale of this risk could have implications for financial stability and the wider macroeconomy. Estimates of the scale of the impact of stranded assets vary significantly and rely on assumptions about the transition to a net zero economy and how companies' resources, projects, and products fit within those new parameters. Some estimates put the magnitude of the potential discounted global wealth loss between $1 trillion to $4 trillion owing to the rates of technological change in energy efficiency and renewable power.

5.48 For the UK, a recent study aggregating the exposure of UK financial institutions to the 26 largest oil and gas companies (around 60% of the publicly traded oil and gas sector) estimates the size of the exposure to be equivalent to 2.1% of UK GDP. The resilience of the UK financial system to climate-related financial risks will be tested in the Bank of England's climate scenario exercise, with the results released in 2022. This will create and test a rich dataset and provide the most accurate assessment of the UK financial system's exposure to climate change to date, covering both physical and transition risks, for all large UK-based banks and insurers.

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33 'Offshore Wind Cost Reduction Task Force Report', Offshore Wind Cost Reduction Task Force, 2012.

34 'Offshore Wind Cost Reduction Pathways Study', The Crown Estate, 2012.

5.49 Other financial institutions are also exposed to carbon-intensive assets. There is some evidence to suggest that, in the UK, the largest pension funds are starting to divest from assets in high carbon sectors, with the government-backed National Employment Savings Trust fund starting to divest from firms involved in coal mining, oil from tar sands and arctic drilling.[35] However, this will not fully reduce exposure to other fossil fuel extraction techniques, nor other carbon-intensive industries and firms.

5.50 To help businesses and investors plan for this shift, government can offer certainty to financial institutions and reduce the risk of market volatility: the use of clear and transparent signalling; phasing in long-term climate and energy policies; and, avoiding aggressive regulatory cliff edges relative to asset life in the targeted industry or technology group. The accurate evaluation and disclosure of climate-related risks by firms can further help financial institutions, policy makers and consumers consider and manage this risk. As set out in Chapter 1, the government is already taking steps to support economy-wide disclosure. While this will not completely remove the risk associated with stranded assets, orderly policy and accurate disclosure will limit the risk of significant financial shocks.

35 'Nest going net-zero to support green recovery', Nest, 2020.

# Chapter 6

# The fiscal implications of the net zero transition

Unmitigated climate change is a significant fiscal risk. However, the transition also has material fiscal consequences that will need to be managed in line with the government's fiscal principles. These fiscal pressures are large in isolation and occur alongside wider long-run pressures on the public finances over the coming decades.

The primary impact is a large and relatively rapid structural shrinking of the tax base as motorists move away from using petrol and diesel vehicles. This leads to a significant and permanent fiscal pressure, which may not be offset by the temporary revenues that could be generated by making polluters pay more through expanded carbon pricing. Therefore, as set out in the government's Ten Point Plan, motoring taxes will need to keep pace with these changes during the transition to ensure the UK can continue to fund first-class public services and infrastructure.

As set out earlier in the report, there is significant technology and cost uncertainty with carbon abatement, and choices on how taxpayer support might address market failures that prevent adequate levels of private investment in different areas. The government has already set out ambitious capital investment plans in support of the UK reaching net zero. If there is to be additional public investment to support decarbonisation, it may need to be funded through additional taxes or reprioritised from other areas of government spending. This approach is necessary given the fiscal pressures that will materialise across the transition, and the need to ensure sustainable public finances. Where, over the 30-year transition, governments choose to increase public investment in decarbonisation above existing levels, additional revenues from polluters via expanded carbon pricing could be used to offset this additional investment – reducing the need to raise other taxes.

In considering how to replace the lost tax revenues, government will need to consider both its ability to fund public services and other public policy objectives of Fuel Duty, such as reducing road congestion and promoting the uptake of electric vehicles.

## Overview

6.1 There is a strong consensus that global action to mitigate climate change is essential for prosperous and sustainable economies over the long run. Taking action is likely to reduce the costs that climate change would have on businesses, consumers and government. Furthermore, the increased investment required to transition to net zero creates opportunities for growth and employment.

6.2 Action on decarbonisation is therefore part of the government's commitment to strong public finances. However, depending on choices made by the government during this 30-period, the transition to net zero could have potentially significant implications for the UK's fiscal position. These impacts will need to be managed effectively and in line with the government's fiscal strategy.

6.3 The Office for Budget Responsibility's recent Fiscal Risks Report (FRR)[1] contains a range of analysis assessing the fiscal implications of climate change and policy action to achieve net zero. One of the main conclusions of the FRR is that the fiscal costs of transition could be substantial – albeit smaller than the cost of failing to control climate change. This conclusion supports the government's commitment to a net zero transition that ensures fiscal sustainability.

## Structural changes in the tax base and economy

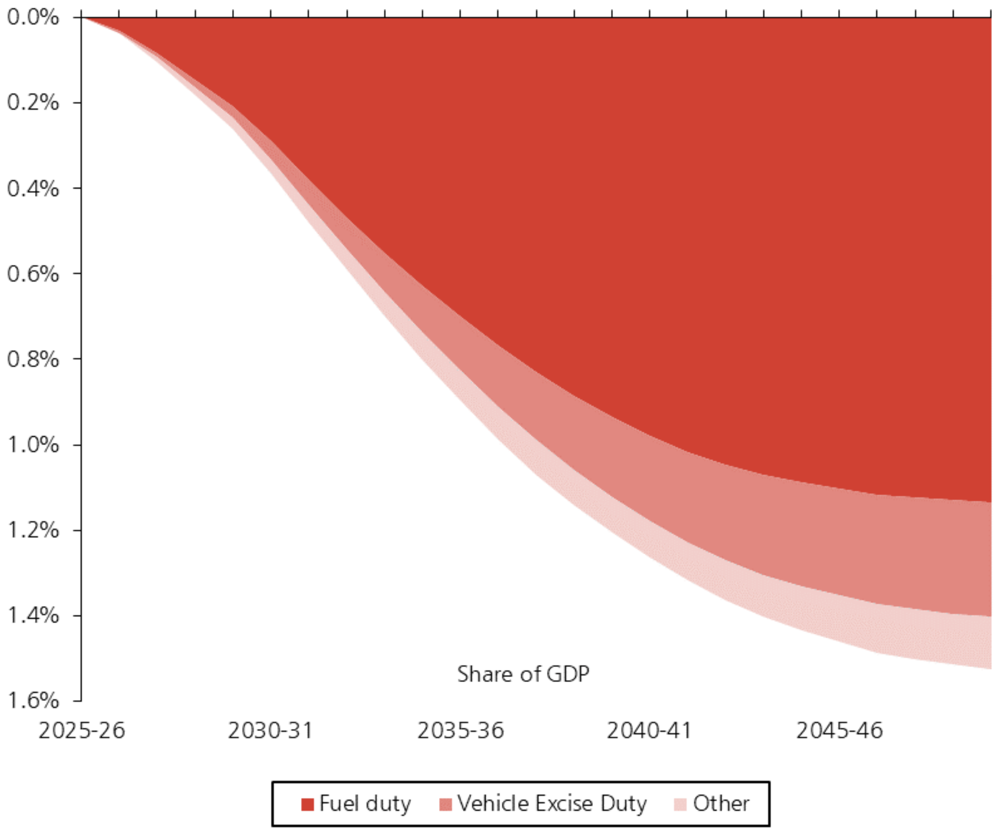
6.4 The largest impacts of the transition on the public finances will stem from permanent changes to behaviour that feed through to the tax system. Primary among these is the loss of significant amounts of tax revenue as the economy shifts away from the use of fossil fuels. This principally concerns revenues from Fuel Duty and Vehicle Excise Duty (VED), amounting to £37 billion in 2019-20 – equivalent to 1.7% of GDP.[2][3] Were the current tax system to remain unchanged across the transition period, tax receipts from most fossil fuel related activity will decline towards zero during the first 20 years of the transition, leaving receipts lower in the 2040s by up to 1.5% of GDP in each year relative to a baseline where they stayed fixed as share of GDP (Chart 6.A). The OBR's FRR reaches a similar conclusion on the size of this risk, highlighting the impact that these lost revenues can have on the long-run sustainability of the public finances.

1 'Fiscal Risks Report', Office for Budget Responsibility, 2021.

2 The Interim Report set out the full set of taxes that are risk from decarbonisation. These are: Fuel Duty, Vehicle Excise Duty, Landfill Tax, Emissions Trading Scheme, and the Carbon Price Floor.

3 Tax revenue and GDP figures used for 2019-20 are as forecast in 'Economic and fiscal outlook – March 2021', OBR, 2021

## Chart 6.A: Reduction in tax revenues from decarbonisation




*Source: HM Treasury calculations*

6.5 Further permanent impacts to the public finances would come from broader economic changes over the transition, including the impact of regulation. The overall assessment of the impact of the transition on the economy is that the net economic impact is uncertain but probably small by 2050. However, this aggregate assessment masks changes at a sectoral and household level. Some sectors will grow and expand, while others will decline. Depending on the relative productivity of these sectors and the amount of tax revenue they contribute, this will also have implications for revenues.

6.6 The impact on business and employment tax revenues through this channel should be relatively small due to the limited exposure of revenues to companies and employees in high emission sectors. Those sectors responsible for 63% of industrial emissions pay just 14% of PAYE and Corporation Tax receipts.[4] The government will continue to assess the broader macroeconomic impacts that will arise during the transition and the implications for the public finances.

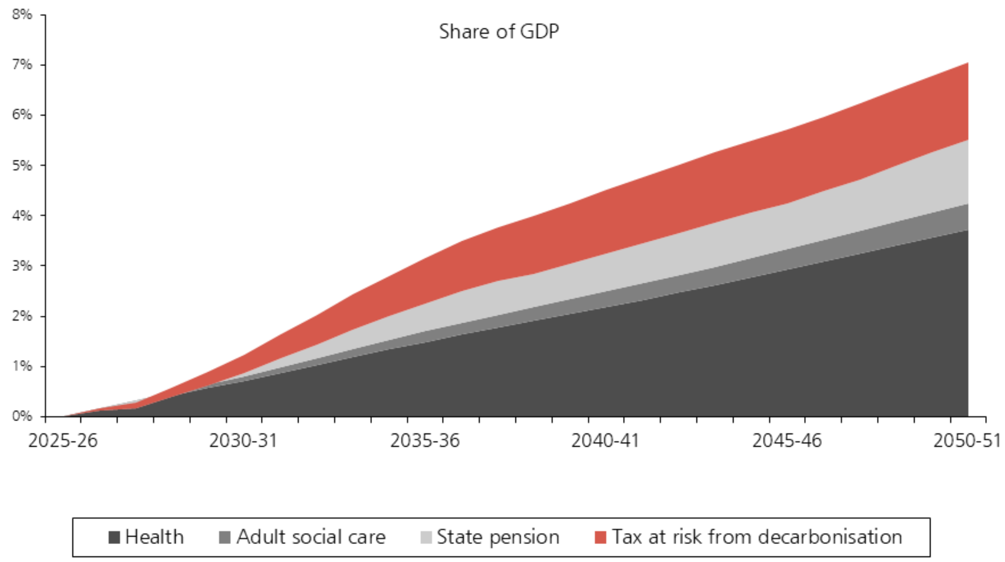
[4] Net Zero Review: Interim Report, HM Treasury, (2020); ‘Atmospheric emissions’, Office of National Statistics (ONS), 2020; ‘Income Tax deducted from pay by industry statistics’, HM Revenue & Customs (HMRC), Pay As You Earn (PAYE) deducted from pay by industry, 2019; and ‘Corporation Tax Statistics’, HMRC, (2020).

# Fiscal sustainability and intergenerational fairness

## Public finances

6.7 Over the period up to 2050, the OBR anticipates that the public finances will come under increasing pressure from factors beyond climate change, as demographic and other trends increase the costs of providing health, social care and state pensions. [5] Chart 6.B shows how these existing structural pressures would increase borrowing in 2050-51 by 5.5% of GDP, relative to 2025-26.[6] The lost tax revenues, if not replaced, would further increase the structural pressure on borrowing in 2050-51 to 7.0% of GDP.[7]

### Chart 6.B: Long-term fiscal pressures[8]




*Source: OBR, HM Treasury calculations*

6.8 Furthermore, the COVID-19 pandemic and the government's response to support jobs and livelihoods has led to elevated levels of borrowing and debt. The government's fiscal policy, as set out at March Budget 2021, prioritised supporting the economy in the short term, while reducing borrowing to sustainable levels once the economy recovers. The March 2021 OBR forecast shows the medium-term outlook for the public finances returning to a more sustainable path, supported by the fiscal repair measures set out in the March 2021 Budget. Underlying debt reaches 97.1% of GDP in 2023-24 but falls marginally in the final years of the forecast, albeit remaining significantly above pre-pandemic levels as shown in Chart 6.C. Over the medium term,

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5 'Fiscal Sustainability Report', Office for Budget Responsibility, 2020.

6 'Fiscal Sustainability Report', Office for Budget Responsibility, 2020.

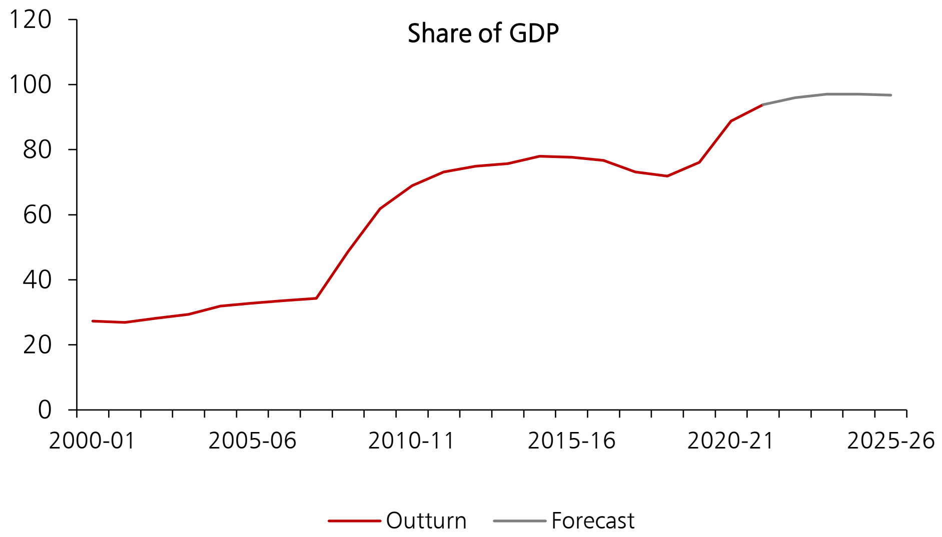
7 This assessment does not include the impact of the additional investment during the transition on GDP, which is uncertain.

8 The long-term fiscal pressures shown in this chart include both expenditure pressures (health, adult social care, state pension) and revenue pressures (tax at risk from decarbonisation). This chart does not reflect the investment in health and social care recently announced in 'Build Back Better: Our Plan for Health and Social Care' in September 2021. The OBR will update its long-run projections in due course.

debt cannot keep rising, and, given the current high level of public debt, close attention must be paid to its affordability.

6.9 Fiscal sustainability is a crucial component of broader economic prosperity. The stability and certainty that comes from sound public finances will support the economic recovery across the UK. Public finance sustainability is also necessary given the risks from high debt and will build fiscal resilience, allowing the government to provide support to households and the economy when it is needed most. With sound fiscal management and careful prioritisation, fiscal sustainability can be achieved while continuing to deliver first-class public services and building the future economy.

### Chart 6.C: Public Sector Net Debt ex BoE




*Source: ONS, OBR Economic and Fiscal Outlook March 2021*

## Intergenerational fairness

6.10 Future generations are among the beneficiaries of net zero investment and, therefore, some might argue that they should pay a portion of these investment costs. This would, however, have negative implications for the public finances, intergenerational fairness and potentially the efficiency of the transition.

6.11 Making future generations pay for the abatement of current generations' emissions deviates from the polluter pays principle – the governing principle for allocating costs in the UK's Environmental Damage Regulations 2009 and proposed Environment Bill 2020. Moreover, future generations would nevertheless also have to meet the costs of adapting to a planet that is at least 1.5°C warmer, with the consequent risks of increased flooding and extreme weather. Lastly, deviating from the polluter pays principle could lead to a less efficient and more costly transition as it stifles the financial incentives for current generation polluters to switch to green alternatives.

## Public investment considerations

6.12 The significant structural change to the tax base will be a natural consequence of decarbonisation. However, there are choices for future governments regarding public investment during the transition to net zero. The OBR's FRR analyses the implications for public spending in supporting the transition by using resource costs estimates from the CCC; these are based on illustrative assumptions and do not represent government policy. The government issued its first Sovereign Green Bond in September 2021 and expects its issuance programme to raise a minimum of £15 billion this year (see Box 6.A). Regardless of future government decisions, public investment is highly likely to constitute a significantly smaller fiscal impact than the pressure of declining tax receipts implied by decarbonisation.

6.13 Previous chapters set out the potential role for targeted public spending. For example, to drive costs down through investment in innovation (Chapter 5), to manage the risk of carbon leakage (Chapter 2) or resolve market failures more generally (Chapter 5). There is a role for the government to mitigate some of the distributional implications of a 'polluter pays' model of decarbonisation. As explained in Chapter 3, public investment is best considered at a sectoral level, given that exposure to the costs of decarbonisation varies significantly depending on factors such as car or home ownership. There is currently significant uncertainty around the technology for meeting net zero, as well as around how the capital and operating costs of those technologies will evolve as they are deployed. Wider developments in policy, markets and technologies will inform decisions on when and how taxpayers should provide support.

6.14 The government is committed to a large public investment programme. The government's objective is to deliver over £600 billion in gross public sector investment over the current parliament, delivering the highest sustained levels of public sector net investment as a proportion of GDP since the late 1970s. Within this envelope, the government has ambitious spending plans to reach net zero. In November 2020, the government set out the Ten Point Plan.[9] This will mobilise £12 billion of government investment to create and support up to 250,000 highly-skilled green jobs in the UK and spur over three times as much private sector investment by 2030. It includes £1 billion of funding to create two carbon capture clusters by the mid-2020s, with another two set to be created by 2030; £525 million to help develop large and smaller-scale nuclear plants, and research and develop new advanced modular reactors; and, £2.4 billion to accelerate decarbonisation in surface transport.

### Box 6.A: Sovereign Green Bond

The government issued its first Sovereign Green Bond (or 'green gilt') in September 2021 – with a second transaction to follow this month. These bonds will help to finance projects tackling climate change and other environmental

[9] 'The Ten Point Plan for a Green Industrial Revolution', HM Government, 2020.

challenges, while financing much-needed infrastructure investment, and creating green jobs across the country.

Sovereign green bond issuance provides a national benchmark for pricing and can create liquidity in the local currency's green bond market, which can encourage corporates and other institutions in the country to issue green bonds. Sovereign issuances can also set standards for other green bond programmes in areas such as the use and management of proceeds and the gathering and reporting of data.

The government expects that the UK's ambitious green gilt issuance programme – with a minimum total issuance size of £15 billion in this financial year – will support the sterling green bond market.

6.15 Over the 30-year transition to net zero, when taking public spending decisions, the government will also need to take account of the economic, fiscal and decarbonisation context at the time. Future plans will be set out as part of the usual Budget and Spending Review processes throughout the transition.

# Carbon pricing

## Carbon price revenue

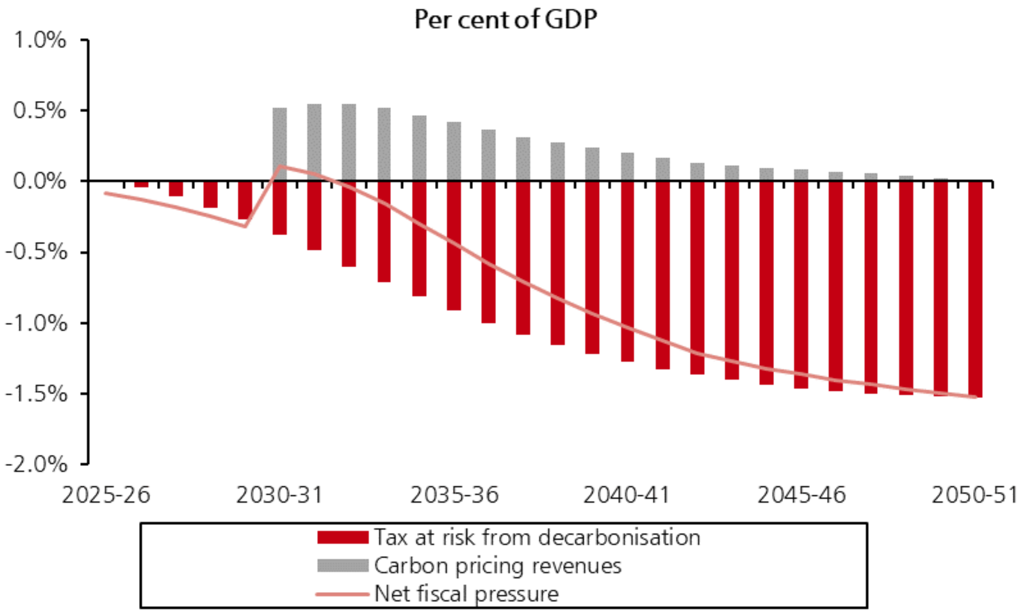
6.16 An expanded carbon pricing regime is important in driving an efficient and fair transition, where polluters pay more. A consequence of this is that it would generate revenues from polluters.

6.17 The UK has two main carbon pricing policies - the Carbon Price Support (CPS) and the UK Emissions Trading Scheme (UK ETS). In practice, the amount generated in the UK by the UK ETS over the long-term will be determined by the cap for allowances, the number of free allowances, the future coverage of emitting sectors and the demand for emissions. The government has also set out its ambition to consult on a net zero consistent cap trajectory. The analysis below is therefore based on an illustrative projection of future carbon prices drawn from the average price levels recommended by the IMF for the 2030s. This shows that an economy-wide carbon price could generate additional revenues equivalent to around 0.5% of GDP initially – a temporary increase in total receipts of around 1.3%. This would not be enough to offset the decline in Fuel Duty and VED during the transition. Similar to other taxes associated with fossil fuels, these revenues would quickly decline as the economy decarbonises and the number of firms paying this tax reduce.

## Additional revenues from polluters through expanded carbon pricing could be used to offset additional investment

6.18 Chart 6.D set outs the potential impacts on the public finances of an illustration of future carbon pricing alongside the projected loss of revenue from fossil fuel related taxes. It assumes for illustrative purposes that current levels of public investment in net zero as a share of GDP are maintained and that carbon pricing policy has expanded by 2030. In this scenario, the net fiscal pressure from the loss of tax revenue related to fossil fuels still reaches around 1.5% of GDP by 2050 because the losses are not offset by temporary revenues from carbon pricing. Without action to offset these pressures the public finances will be put in an unsustainable position. Therefore, delivering net zero sustainably and consistently with the government's fiscal strategy requires expanding carbon pricing and ensuring motoring taxes keep pace with these changes during the transition.

## Chart 6.D: Net change in tax revenues during the net zero transition, disaggregated by source




*Source: HM Treasury calculations*

6.19 While additional carbon pricing revenues, as illustrated above, are not sufficient to offset the reductions in fossil fuel related revenues and are temporary in nature, they can help offset any increases in public investment during the transition. If carbon pricing was assumed to follow the IMF recommended schedule, receipts could be equivalent to around a third of the annual abatement costs in 2030. While there is unlikely to be a direct match in the timing and size of carbon price revenues and public spend on decarbonisation, the general profile will be broadly similar – with less of a need for public investment in the latter years of the transition aligned with a decline in carbon price revenues as the UK approaches net zero.

6.20 The OBR's FRR estimates the potential revenues from carbon pricing to be higher than the illustrative estimate set out above. This largely results from their adoption of a higher carbon price assumption. The FRR derives this assumption from the Bank of England and the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) and the CCC scenarios, while the Net Zero Review[10] derives carbon pricing values from IMF estimates and the estimated cost of greenhouse gas removal technologies in 2050.

6.21 There are choices over the carbon price required to drive the transition to net zero. This means the potential revenues from carbon pricing are uncertain.

[10] These assumptions do not represent government policy, and decisions will be taken as part of the usual Budget and Spending Review processes.

# Annex A
# Methodology

A.1 This section sets out the methodological approach that underpins the analysis in each chapter of this report.

A.2 The Review draws on existing resource costs from the across government and publicly available data sources. No independent estimates of the costs of reaching net zero have been undertaken by HM Treasury as part of this review.

## Chapter 1 Net Zero and the UK economy

A.3 The Review has not attempted a quantitative assessment of the overall macroeconomic impact of the transition to net zero. Work is underway to produce this in the medium-term.

### Resource costs and investment

A.4 In Chart 1.B, HMG analysis has provided an aggregated resource cost estimate. These are bottom-up cost estimates from individual sectors which, together, form an illustrative scenario for the transition to net zero by 2050. The costs are incremental to a counterfactual, or business-as-usual baseline, representing the cost of a low carbon technology relative to what would otherwise be spent in the existing system. The transition to net zero will require capital investments in technologies. Some of these investments may result in additional operating costs (for example hydrogen heating), while others may generate savings in terms of running costs (for example electric vehicles, where maintenance and fuel costs are likely to be lower than for petrol or diesel equivalents). The sum of the additional investment cost compared to the baseline and the operating costs/savings are together called 'resource costs'.

A.5 The most recent cost estimates in the Net Zero Strategy present a net cost, excluding air quality and emission reduction benefits, equivalent to 1-2% of GDP in 2050. Typically, costs are calculated by taking the cost of the new technologies and spreading them over the lifetime of the asset. For the HMG analysis, the costs are calculated on the basis of the upfront investment costs. The benefit of this approach is that it shows the actual point in time of the economic investment, compared to an annualised cost approach, where the technology costs are spread across the lifecycle of their use.

A.6 As with any projection over a 30-year transition, the costs are highly uncertain and will depend on the rate of innovation and technology cost reductions, consumer choices and preferences, policy decisions and potential system-level decisions such as the role of hydrogen in the future UK economy.

A.7 The report considers the investment required to reach net zero, which will have an impact on the macroeconomy. In Chart 1.C, to consider the effect of investment on the macro economy, the OBR's Gross Fixed Capital Formation (GFCF) forecast is used as a baseline of capital investment without net zero and assumes BEIS' sum of capex resource costs are the additional capital investment requirements, above and beyond the GFCF forecast, to achieve net zero.[1]

A.8 Using OBR GDP forecasts which follow current GDP trends, both the GFCF and BEIS' estimated capex costs are interpreted as a share of GDP.[2]

# Chapter 2 Net zero and international competitiveness

## Carbon leakage analysis

A.9 The OECD Trade in Embodied CO2 database (TECO2)3 provides estimates of the embodied CO2 content from fuel consumption in 36 traded industries in 65 countries, including the UK, from 2005 to 2015. Where embodied emissions in traded sectors see large discrepancies, this would imply higher carbon leakage risk.

A.10 $TECO_2$ is a combination of two datasets: the 2018 OECD Inter-Country Input-Output (ICIO) database that captures trade flows and where value is added along the supply chain; and the International Energy Agency's $CO_2$ emissions (IEA-$CO_2$) from fuel combustion database.

A.11 $TECO_2$ brings together emissions data from the IEA $CO_2$ database (IEA-$CO_2$) with ICIO data where the emissions of household final consumption of the 36 industries are mapped to the output in each industry and country. This serves as a consistent estimate of the production-based $CO_2$ intensity of the output of each industry in each country. The database has limitations and its conclusions should be accompanied by important caveats, and the results should be regarded as indicative of an order of magnitude, rather than precise estimates. These caveats include the following:

- In the $TECO_2$ and Trade In Value Added (TiVA) databases, each industry in each country uses fixed proportions of inputs. These proportions do not vary with use or destination (domestic or exports). It would be expected that emissions embodied in exports would differ compared to domestic sales (for example, exporters tend to be more productive than firms which sell only to the domestic market – and higher productivity is associated with lower direct emissions);[4]

1 'Economic and Fiscal Outlook', OBR, 2021; 'Sixth Carbon Budget Impact Assessment', BEIS, 2021.

2 'Economic and Fiscal Outlook', OBR, 2021.

3 Data can be found here: https://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm

4 ONS research paper suggests businesses that report exports may be around 21% more productive than those that do not, when controlling for some business characteristics: 'UK trade in goods and productivity new findings': ONS, 2018.

- Carbon intensity per *unit of value* will be skewed downwards, compared to carbon intensity per *unit*, in countries where per unit prices are higher because of branding/higher quality;
- Some of the variation in carbon intensity between countries may be due to differences in sectoral composition, by country, because of the use of relatively wide sector definitions. Using wide sector definitions also means that figures for trade flows are highly aggregated;
- Carbon intensities are expressed per $million of gross exports. Such data will therefore fluctuate over time for reasons unrelated to carbon intensity (for example, due to exchange rate movements); and,
- The OECD data does not take account of other GHGs like methane or nitrous oxide emissions, which are many times more potent as GHGs than $CO_2$.

A.12 In addition to the limitations in the data, some assumptions have been undertaken to produce the analysis in Chapter 2:

- The chapter uses summarised sector names, for example, "Refineries" refers to the OECD's International Standard Industrial Classification (ISIC) sector "Coke and refined petroleum";
- OECD data on carbon intensity in gross exports is used to compare the UK intensity with OECD and non-OECD aggregates. These estimates do not include intra-OECD and non-OECD trade. However, this is unlikely to have a significant impact on intensity figures. Some differences may occur, for example, due to a different mix of sectoral exports (and associated intensities) for intra-regional trade to those exported externally; and,
- TiVa data have been used to establish trade measures. These are unlikely to fully conform to other datasets but are consistent with the $CO_2$ emission data.

A.13 The degree to which a sector is open to international trade is also an important factor in determining carbon leakage risk. OECD data from TiVA has been used to establish trade openness measures, which is unlikely to fully conform to other domestic trade datasets but is consistent with the $CO_2$ emission data.

A.14 Trade openness for each sector is calculated by summing imports and exports and dividing by total supply. Total supply is the sum of a sector's gross output (production) and imports. Domestic demand is also considered in this analysis and is calculated as gross output plus imports minus exports. The data used in this calculation excludes re-imports and re-exports.

## Chapter 3 Understanding households' exposure to the net zero transition

A.15 Households will experience varying levels of exposure to the transition. The analysis in Chapter 3 presents an illustrative picture of how the overall costs of the transition to net zero might affect households. This is highly uncertain and makes strong assumptions about the estimated level of costs, the incidence between firms and households, all costs being passed on to households (via new investments for households or higher prices and bills), and how households respond.

A.16 Charts 3.D and 3.E show the embodied carbon footprint of consumption by household income decile. They combine spending data from the Living Costs and Food (LCF) survey[5] and Department for Environment, Food & Rural Affairs' (Defra) Carbon Footprint data.[6] The Defra Carbon Footprint data traces emissions for goods and services through from source to final consumption goods. LCF data on the consumption of these goods is used to allocate this carbon to households (assuming constant CO2 equivalent per pound within each consumption category).[7]

# Chapter 4 Factors affecting the degree of household exposure to the power, housing, and electric vehicle transitions

## Power

A.17 The analysis in this chapter presents an illustrative scenario of future domestic electricity bills. Projecting household electricity costs out to 2050 is challenging as there are many factors which drive future bills that are highly uncertain.

### Household electricity prices

A.18 Chart 4.B relies on a number of simplifying assumptions to illustrate how future electricity costs could evolve over the coming decades, for example:

A.19 The future generation mix[8] is a key driver of uncertainty in future prices. This analysis is therefore based on BEIS' Sixth Carbon Budget Impact Assessment Core scenario,[9] modelled in BEIS' Dynamic Dispatch Model (DDM).

A.20 Significant uncertainty around the commercial cost of hydrogen for heating mean that, for illustrative purposes, much of heat is electrified through heat pumps. Hydrogen is however assumed to play a role in flexible clean energy generation.

A.21 Electricity demand is assumed to be around 470TWh by 2035 and more than 680TWh by 2050. The analysis does not model different aggregate energy demand scenarios. This is however a key driver in the future uncertainty of consumer costs.

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5 'Living Costs and Food Survey', Office of National Statistics (ONS), 2014/15-2016-17 - data is presented in the fiscal year 2020-21.

6 'UK's Carbon Footprint' (2016 data), Department for Environment, Food and Rural Affairs (Defra), 2020.

7 The analysis uses territorial emissions from the Defra Carbon Footprint data (in line with the rest of this report). The household consumption data in the LCF does not distinguish between spending on domestic versus imported goods (or goods with part of their supply chain imported). Therefore, total spending is used to apportion domestic emissions. This implicitly assumes that all households are equally likely to consume domestic and imported goods. Or put another way, households' carbon footprints are not lower if they disproportionately consume imported products.

8 Generation mix uncertainty has not been accounted for in this analysis and there are many potential future generation mixes consistent with the Sixth Carbon Budget and achieving net zero.

9 'Impact Assessment for the sixth carbon budget', BEIS, 2021.

A.22 The long-term future policy and financing mechanisms for low carbon deployment are uncertain, and therefore the analysis assumes that Contracts for Difference (CfD) fund all low carbon deployment in electricity generation out to 2050. Additionally, the Capacity Market (CM) is assumed to remain as the support mechanism for ensuring security of supply.

A.23 In a future grid supported by CfDs, there are major challenges with estimating future strike price outcomes, due to the competitive nature of auction allocations. This analysis assumes that strike prices are constant across all scenarios at £50/MWh (2020 prices), in line with the last auction outcome (AR3). It is not unreasonable to expect lower strike prices in the future but estimating the level at which they will plateau is very difficult.

A.24 Similarly, the future carbon price is uncertain, and so this analysis assumes the total carbon price in 2050 is equivalent to the central appraisal value of around £378/t$CO_2$ (2020 prices)[10] for all scenarios.

A.25 To capture an element of policy support for low-income households, both the Energy Company Obligation (ECO) and Warm Home Discount (WHD) are held constant in real terms. Given significant uncertainty in future efficiency, no additional benefits from ECO beyond the end of ECO 4[11] are modelled.

A.26 A constant 2% margin for suppliers is assumed, this is in line with Competition and Markets Authority and Ofgem estimates on reasonable margins when the Price Cap was introduced.[12] Similarly, future operating costs are assumed to be in line with Ofgem's assessment of efficient supplier operating costs, adjusted for inflation. VAT for electricity is assumed to remain constant at 5%.

## Household electricity bills

A.27 Chart 4.D compares an illustrative average bill for a household in 2019 and an illustrative average bill for a household in 2050. In 2019, this analysis looks at a household that uses a gas boiler to heat their home and relies on a petrol car for private transportation. By 2050, the household is assumed to have replaced their gas boiler with an electric Air Source Heat Pump (ASHP) and replaced their petrol car with an Electric Vehicle (EV). Remaining electricity consumption (for example for lighting) is broadly similar across 2019 and 2050.

A.28 The results need to be interpreted and used cautiously. The sum of potential uncertainties in Chart 4.D amount to a range that is almost half of the bill estimate in 2050, and still does not account for all factors that drive uncertainty in future bills. The evolution of future funding mechanisms (and wider taxation decisions) and the level of government support together with the decarbonisation pathway and the role for hydrogen and green gas could mean that the actual range of uncertainty in

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[10] This figure is an estimate consistent with decarbonisation in the power sector rather than economy wide decarbonisation. An alternative price of £160/t$CO_2$ is used elsewhere in the report as an estimate of the cost of a basket of negative emissions technologies.

[11] The fourth phase of Energy Company Obligation (ECO4), which is an obligation on energy suppliers to install energy efficiency and heating measures in fuel poor and low-income homes. As part of the government's Ten Point Plan the government committed to extend the ECO from 2022 to 2026.

[12] 'Default Tariff Cap: Decision- Overview', Ofgem, 2018

future bills is much larger than presented. Only those policies with agreed funding and developed to a sufficient degree of detail are included in the analysis.

A.29 In order to develop Chart 4.D a number of assumptions across the different transitions have been made. These are set out below.

- Power costs:
  - Electricity prices are consistent with the price scenario described above for electricity; and,
  - The power consumption element of Chart 4.D assumes an electricity demand of 3.7MWh per household, with the sensitivity range based on average consumption for EPC B and EPC E homes.
- Heating costs:
  - Future power and heating consumption depend on home and product efficiency, as well as the extent to which appliances are electrified. While electricity products are expected to get more efficient over time, it is not clear that this translates into lower electricity consumption. Similarly, changes in technology and consumer preferences out to 2050 are also expected, making it difficult to infer a clear direction of travel for average household electricity consumption. This analysis bases ranges on current Standard Assessment Procedure efficiency for homes;
  - Heat consumption for a household with an ASHP and a given heat demand depends on two main factors: the efficiency of the house and the technical efficiency of the ASHP. There's uncertainty in both factors out to 2050 but in general it could be expected that these would improve from current levels. This analysis considers a range in consumption based on both, with the high scenario based on current levels; and,
  - The assumptions feeding into the heating consumption element of Chart 4.D include the assumption that the base gas heating demand is equal to 13.2MWh.[13] Gas prices were taken from BEIS' Supplementary Guidance.[14] An uplift of 10% is applied to this to account for the difference in the way that an ASHP heats the home in comparison to a gas boiler. The gas boiler efficiency is assumed to be 84%[15] and ASHP technical efficiency is assumed to be 244% to 350%,[16] with a central estimate of 300%. Building efficiency in 2050 is assumed to be between 0% to 22%, with a central estimate of a 11% reduction in energy use.[17]
- Transport costs

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13 'National Energy Efficiency Data-Framework (NEED)', BEIS, 2020

14 'Green Book Supplementary Guidance', BEIS, 2020

15 'In-situ Monitoring of Efficiencies of Condensing Boilers and use of Secondary Heating', DECC, 2009

16 'Final Report on Analysis of Heat Pump Data from the Renewable Home Premium Payment Scheme' UCL Energy Institute, 2017

17 This is based on BEIS' internal assessment of the maximum potential for heat demand reduction as a result of energy efficiency measures across the housing stock. Additional demand reduction may be achievable in practice, but it would likely require relatively expensive measures.

- The transport consumption element of Chart 4.D is based on the assumption that the average kilometres driven per car is 12,000 per year, which is an average of the low and the high estimates, of roughly 10,000 and 13,000 kilometres per year respectively. The low and high estimates are taken from DfT's Road Traffic Forecasts,[18] specifically Scenario 6 (Extrapolated Trips) and Scenario 7 (Net Zero) respectively. The uncertainty range for EV running costs is based on these estimates. Road fuel (petrol) prices were taken from DfT's Transport Analysis Guidance (TAG) data book.[19] The household is assumed to charge its EV entirely at home, although this is unlikely to be the case.

## Housing

A.30 Chapter 4 analyses the potential costs to households of a transition to greater energy efficiency and low carbon heating in existing domestic buildings.

A.31 Calculating the exposure to households is complex. In particular, it is challenging to estimate the costs facing households in the future, given the uncertainty around heat decarbonisation pathways and costs. This analysis therefore focuses on the current situation, and what the costs would be to households of decarbonising now.

A.32 To do this, the upfront cost estimates presented in Charts 4.E and 4.F model a stylised scenario where households acquire: wall insulation, loft insulation, double glazing and an air source heat pump.[20] The analysis assumes that all dwellings that do not currently have these improvements receive them, but in reality, different dwellings will have different requirements.

A.33 The English Housing Survey[21] and Fuel Poverty Survey[22] are used to determine the existing measures households have and the type of additional retrofitting required. This includes whether cavity or solid wall insulation is needed and the size, type and current EPC rating of dwelling.

A.34 Costs of insulation measures are taken from University College London (UCL).[23] The capacity of heat pump required is derived after accounting for energy efficiency improvements and the characteristics of the property. The costs of heat pump installation are internal BEIS estimates (caveated that not every dwelling can receive a heat pump).[24] This analysis uses current cost estimates inclusive of VAT and does not account for potential future cost reductions. This analysis is based on the English Housing Survey, and therefore only focuses on England.

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[18] 'Road traffic forecasts 2018', Department for Transport, 2018.

[19] 'Transport Analysis Guidance Data Book', Department for Transport, 2020.

[20] Other low carbon heat sources are possible, and different technologies will be required for different properties, but have not been modelled here.

[21] 'English Housing Survey', MHCLG, 2018.

[22] 'Fuel Poverty Survey', BEIS, 2018.

[23] 'Analysis Work to Refine Fabric Energy Efficiency Assumptions for use in Developing the Sixth Carbon Budget', Bartlett School of Environment, Energy and Resources (BSEER), University College London (UCL), 2020.

[24] 10% of stock is unsuitable for a LSASHP due to insufficient insulation. Space constraints, noise pollution and current limits to the electricity network also make heat pumps infeasible for every dwelling.

## Housing Sensitivity

A.35 Independent estimates of total costs tend to vary depending on what is included: replacement rates (which depend on rollout profile), new builds (which may account for 20% of housing stock by 2050,[25] alternative low carbon heat sources, cost reductions over time, and behavioural measures.

A.36 The costs of decarbonising the housing stock that are presented in Chapter 4 are very uncertain. Costs may vary for a number of reasons:

- Boiler costs: The analysis assumes upfront costs can be reduced by installing a heat pump when a new boiler is needed (not accounting for interim heating costs, and assuming every household has a gas boiler);[26]
- Variation in costs of improvements: The upfront costs in the analysis are averages, and alternative sources shown in Table A.1 suggest higher or lower figures could be possible;

### Table A.1: Range in improvements costs[27]

| Improvement type | Highest cost | Lowest cost |
|---|---|---|
| Wall insulation | £11,600 | £590 |
| Loft insulation | £3,500 | £180 |
| Double glazing | £10,000 | £1,200 |
| Air heat pump installation | £21,550 | £4,430 |

- Mortgage interest rates: The upfront costs could be spread by adding them to a mortgage, but this will be sensitive to changes mortgage interest rates and the length of the repayment period;
- Exposure of non-owner occupiers: The costs faced by private and social renters will depend on whether landlords pay the upfront costs of improvements or pass them through to tenants;
- Cost of low carbon heating: Heat pump installation and running costs are predicted to fall in the future. There are also alternative low carbon heat sources, such as hydrogen and community heat schemes, which could impact on the cost to households; and,
- Energy bills: The impact of decarbonisation on energy bills could change in the future, for example if gas and electricity prices were rebalanced.

[25] 'A report for the Committee on Climate Change: The costs and benefits of tighter standards for new buildings', Currie and Brown, (2019).

[26] The England Housing Survey finds that 90% of dwellings have a boiler.

[27] Retrofitting costs: 'What does it cost to retrofit homes', BEIS, 2017. Heat pump high cost: The Cost of Installing Heating Measures in Domestic Properties', Delta-ee, 2020. Heat pump low cost: 'The Sixth Carbon Budget: Buildings', CCC, 2020.

## Electric Vehicles

A.37 The next section of this chapter sets out the impact to households of the transition to electric vehicles, using descriptive statistics from publicly available sources.

A.38 All methodological details are included within the chapter.

# Chapter 5 A low-cost transition

## Elasticities estimate

A.39 Table A.2 outlines the studies included in Chart 5.A of Chapter 5, sourced as part of a literature review assessing existing price elasticity of demand figures across different sectors of the economy.

A.40 It is important to note that many of the studies identified as part of the literature review were published several years ago. Technology choices and consumer awareness may have evolved since some of these studies were published. It is also important to note, as highlighted in Table A.2, that not all studies are based on UK data. These factors will affect the relevance and validity of the studies and therefore the results should be treated carefully.

### Table A.2: Studies in literature review

| Area | Study | Elasticity value | Year | Country |
|---|---|---|---|---|
| Transport | Demand elasticities for car trips to central London (Transport for London) | Short Run (SR): -0.1 to -0.47, Long Run (LR): -0.3 | 2008 | UK |
| Transport | Elasticities of gasoline demand in Switzerland (Baranzini and Weber) | SR: -0.09, LR: -0.34 | 2013 | Switzerland |
| Transport | The Demand for Automobile Fuel: A Survey of Elasticities (Graham and Glaister) | SR: -0.3 | 2002 | UK |
| Transport | Analysis of the dynamic effects of fuel duty reductions (HMRC) | SR: -0.07, Medium term: -0.13 | 2014 | UK |

| | | | | |
|---|---|---|---|---|
| Transport | The effectiveness of gasoline taxation to manage air pollution (Sipes and Mendelsohn) | SR: -0.4 to -0.6, LR: -0.5 to -0.7 | 2001 | USA |
| Transport | The empirical evidence of a gasoline tax on CO2 emissions reductions from transportation sector in Korea (Kim et al.) | SR: -0.33 | 2011 | South Korea |
| Transport | Estimate of the impact on emissions of a reduction in APD In Scotland (Transport Scotland) | SR: -0.2 to -0.7 | 2014 | UK |
| Agriculture | Development of a land use module for the applied economic model NEMESIS (Boitier) | SR: -0.01 | 2011 | UK |
| Agriculture | Estimating the Elasticity of Demand and the Production Response for Nitrogen Fertiliser on Irish Farms (Breen et al.) | SR: -0.396 | 2012 | Ireland |
| Buildings | Price elasticity of electricity demand in the US (Burke and Abayasekara) | SR: -0.1, LR: -1.0 | 2018 | USA |
| Buildings | Price elasticity for Energy use in Buildings in the United States (US Energy Information Administration) | SR: -0.03 to -0.25, LR: -0.15 to -0.29 | 2021 | USA |

| | | | | |
|---|---|---|---|---|
| Energy Demand | Meta-Analysis on Price elasticity of energy demand (Labandeira et al.) | SR: -0.15 to -0.23, LR: -0.36 to -0.72 | 2015 | Global |
| Energy Demand | Decoupling of industrial energy consumptions and CO2 emissions in energy intensive industries in Scandinavia (Enevoldsen et al.) | SR: -0.35 to -0.44 | 2007 | Denmark, Norway, Sweden |

## Relative Carbon Prices

A.41 Chart 5.B in Chapter 5 summarises work by Oxford Energy Institute[28] on relative carbon price incentives. The lines have been rebased to show the price signals on different forms of energy consumption. The analysis looks at government policies to understand the scale of the incentive to decarbonise, relative to carbon emitted.

# Chapter 6 The fiscal implications of the net zero transition

A.42 Chapter 6 sets out analysis of the potential implications of the net zero transition on tax receipts. The chapter also places this in a broader fiscal context.

## Net reduction in tax revenues

A.43 The chapter shows the potential impact on tax revenues that results from the transition. This includes the projected loss of revenues from fossil fuel related taxes and additional revenues from carbon pricing.

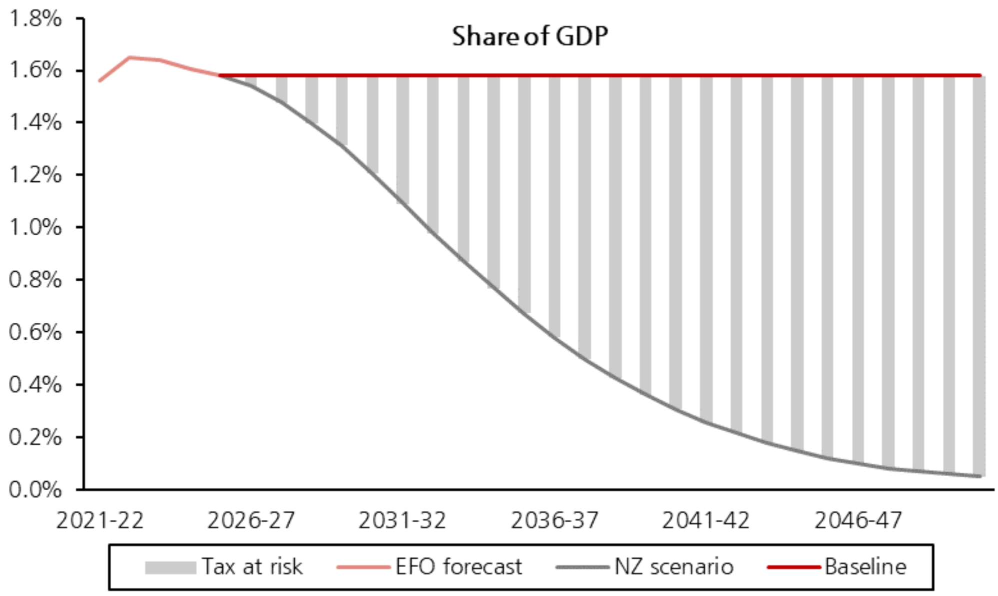
A.44 Tax revenues from fossil fuel related activities will decline as the economy decarbonises. The Net Zero Review interim report identified the taxes that are most at risk from decarbonisation, which include Fuel Duty, Vehicle Excise Duty, Landfill Tax, the Emissions Trading Scheme, and the Carbon Price Floor. Without changes in policy, the government expects these revenues to decrease to zero by 2050.

A.45 The analysis presents a projection of the change in tax revenues over time, calculated as the difference between projected revenue as a share of GDP in each year, and revenue as a share of GDP in 2025-26. The pace of decline in the Fuel Duty and Vehicle Excise Duty tax bases has been modelled using projections from Department for Transport on the demand for fuel and number of EVs up to 2050 (although it should be noted that these projections come with a high degree of uncertainty). The pace of decline in the three other taxes is informed using a simpler

28 'Current Economic Signals for Decarbonisation in the UK', Oxford Energy Associates, 2018.

approach which uses a projection of emissions to approximate the decline in these tax bases.

### Chart A.3: Modelling tax at risk across the transition




*Source: OBR, DfT, BEIS and HMT*

A.46 This chart does not show a fiscal impact from public spending on net zero.

## Gross Domestic Product projection

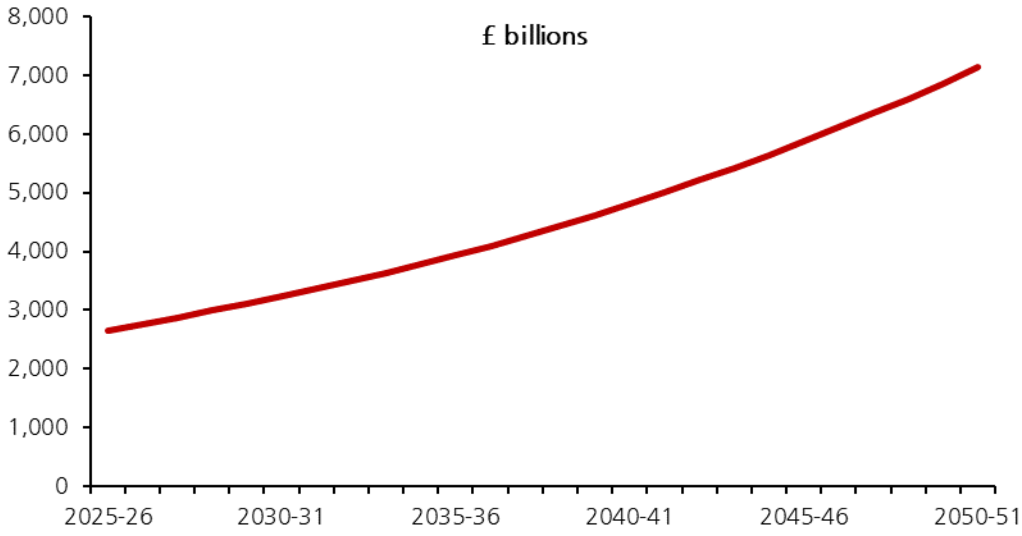
A.47 The report presents changes in tax revenues over the transition as a proportion of GDP. Presenting fiscal outputs in this way is standard across long-run analysis of the public finances, as it enables comparisons of fiscal impacts at different points in time when economic growth and inflation may change the nominal size of these impacts considerably.

A.48 The approach taken here does not consider the indirect economic impacts of the transition or public finance decisions. Therefore, the GDP projection used in the transition scenario does not respond to changes in the structure of the economy that will take place across the period.

A.49 The GDP projection is constructed following the approach used by the OBR in the Fiscal Sustainability Report. Nominal GDP growth is modelled as equal to the combined growth of productivity, employment and inflation. This nominal GDP growth rate is applied recursively to the GDP estimate of the previous year, starting with the GDP estimate for the fiscal year 2025-26 from the March 2021 Budget forecast.

A.50 References to 2019-20 GDP figures in this chapter are also from the OBR's March 2021 Economic and Fiscal Outlook to ensure consistency with the long run GDP projections explained above.

### Chart: A.4: Gross Domestic Product (nominal)




*Source: OBR*

## Long-run fiscal pressures

A.51 Chapter 6 of the report also presents net zero pressures alongside other public finance pressures that will materialise over the coming decades, such as health, pensions and social care spending.

A.52 This draws on existing analysis from the OBR's Fiscal Sustainability Report 2020, which uses demographic and other trends to project the amount of government spending that will be required to meet these commitments.[29] This report presents this OBR analysis by first converting the data to show the size of the fiscal pressure relative to a base year of 2025-26.

A.53 The fiscal impact of these pressures is therefore defined as the fiscal cost as a share of GDP in addition to the fiscal cost in 2025-26.

## Paying a carbon price

A.54 It is assumed for the purposes of producing fiscal analysis that there is an economy wide carbon price by 2030 set at £50/t$CO_2$, which increases linearly to £160/t$CO_2$ in 2050. This schedule is set out in Chart A.5. These prices are not an indication of government ambitions. The opening price is taken from the IMF[30] and the 2050 price is an estimate from the literature of the cost in 2050 of a basket of greenhouse gas removals technologies.[31] The ability to offset rather than abate emissions provides a ceiling on the marginal cost of abatement and therefore on the carbon price: for any abatement costing above the ceiling price, polluters would choose to offset their emissions rather than pay for it.

A.55 The carbon pricing schedule set out in Chart A.5 is used to generate the size of the revenues (transfers from polluters to taxpayers). The revenues are calculated by multiplying the given carbon price in each year with the level of emissions in each year. The level of emissions in each year are target-consistent, which corresponds to

[29] Fiscal Sustainability Report 2020, OBR, 2020.

[30] 'Fiscal Monitor: How to Mitigate Climate Change', IMF, 2019.

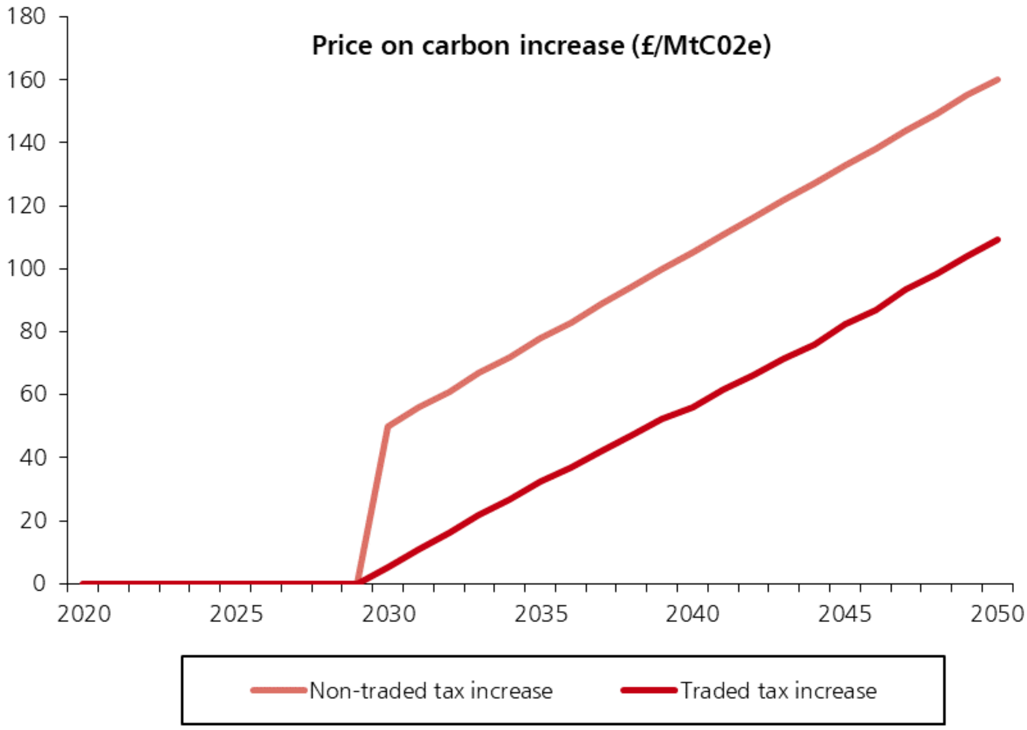
[31] 'How to price carbon to reach net-zero emissions in the UK', J. Burke, et. Al, 2019.

the emissions trajectory that is in accordance with all of the carbon budgets, as set out in Chart A.6.

A.56 The costs and revenues presented in this chapter are separate to the total resource costs presented elsewhere in the report and have been calculated for the purposes of the fiscal analysis only. They are therefore not directly comparable to the other costs presented in this report, which rely on different methodological approaches.

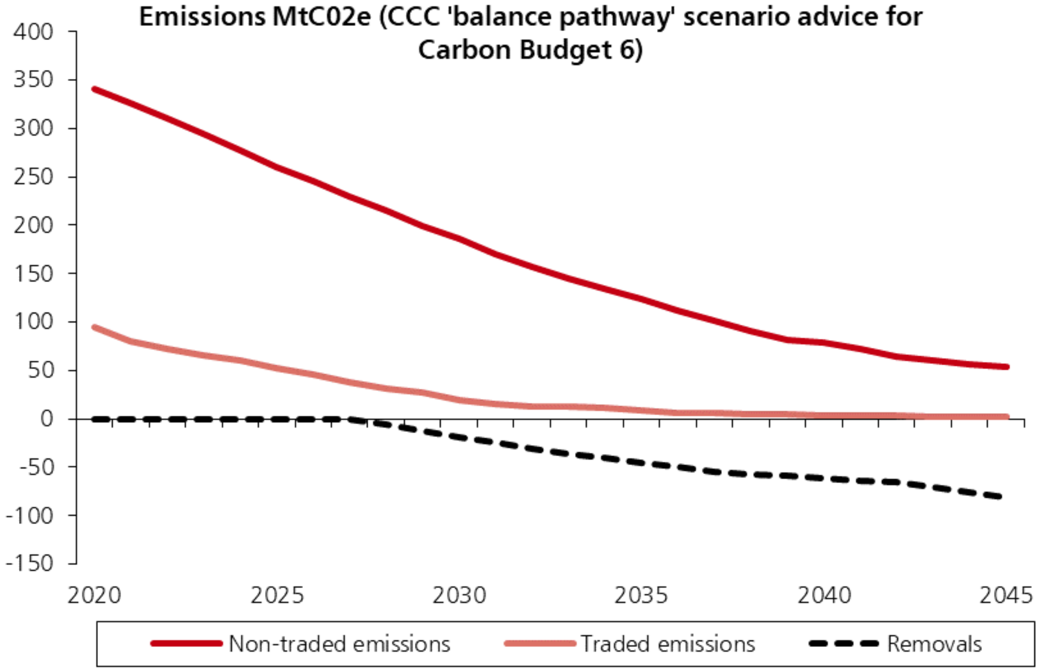
A.57 The prices and revenues captured in this analysis are additional to those experienced to date. For that reason, the carbon price and the emissions that are already traded under existing schemes start at zero in 2030 because it is assumed that they are already paying a carbon price equivalent to £50/t $CO_2$. Non-traded sectors face the full price impact on their emissions. This difference is reflected in Chart A.5.

## Chart: A.5: Carbon price increase per MtCO2e




*Source: HM Treasury calculations*

## Chart: A.6: Traded and non-traded emissions in the Balanced Pathway




*Source: 'Sixth Carbon Budget report', Climate Change Committee, December 2020*

# Annex B

# Net Zero Review Interim Report: Labour Market Analysis

B.1 The transition will be a dynamic process and one that will take place over 30 years. Beyond taxation and public spending that directly apply to households, the transition to net zero will affect households directly through the goods and services they buy and indirectly through the costs on businesses:

- **Labour market:** Individuals work at firms that emit carbon in their production processes. To the extent that decarbonisation reduces worker productivity, it may cause real wages and labour market opportunities in these firms to decline over time. On the other hand, the transition will also create new economic and employment opportunities as new sectors emerge, as set out in Chapter 2;

- **Consumer prices:** Carbon is emitted in the production of products that households consume, both directly in the consumption of energy and fuel, and indirectly through embodied carbon in the supply chain. Regulation, taxation or abatement activity may increase the prices of these products. At the same time, lower costs in other areas will make some goods more affordable; and,

- **Business profits:** Where businesses become less profitable, this will pass through to the households that own them. The transition will spur a reallocation of capital across the economy. New, low carbon sectors will be new sources of profit. These profits pass through to households through dividends and through the value of their assets.

B.2 These channels are complex, and the final costs may pass through to households through all three channels. The transition is a dynamic process that will take place over several decades, and its impact on individual households will ultimately depend on a range of factors including: the development of new low carbon sectors in the UK; the pace of transition and policy levers chosen; the price of low carbon alternatives to households and businesses' current activities; and the dynamism of the labour and capital market. Nevertheless, the analysis does underline the importance of managing the transition in a way that minimises the risks of adverse impacts for certain groups.

## Households, emissions and the labour market

B.3 This section considers how households might be affected by the transition through their employment and wages. The analysis shows sectors and types of jobs that are currently associated with high carbon emissions. It should not be seen as reflecting the final impact of the transition on those sectors, jobs or employees; this will depend on the policy levers chosen to support the transition, how easily and cheaply these sectors can decarbonise and their international exposure and competitiveness. And for employees, it will depend on where and when new employment opportunities emerge in competing, low carbon industries.

B.4 Over the course of the transition, there will be significant changes in the UK labour market. Some of these changes will be directly associated with the transition to net zero, although other technology-driven changes are also likely to be important. Changes in the labour market in one sector may be offset by new employment opportunities elsewhere, including through the expansion of low carbon industries.

B.5 The International Labour Organization (ILO) expects 24 million new jobs and 6 million job losses by 2030 as a result of collective action to meet the goals of the 2015 Paris Agreement. This net job creation is primarily driven by growth in renewable energy, which is expected to be 11% higher than the business-as-usual scenario.[1] The ILO has found that renewable energy growth leads to higher job creation than expanding other energy sources, while reducing emissions.[2] Jobs would also be created in manufacturing and construction, and the economic linkages between sectors mean that employment in services, waste management and agriculture will also grow. For example, over two million jobs will be created worldwide in the manufacture of the electrical machinery required to produce electric vehicles and the generation of electricity from renewables.[3]

## Box B.1: Labour market exposure methodology

The analysis combines ONS data on atmospheric emission by industry[4] and Living Costs and Food Survey[5] employment data to calculate carbon intensity per worker. Carbon intensity is assigned to workers in the Living Costs and Food Survey based on the industry in which they work.[6]

This is then used to calculate the average carbon intensity for specific occupations and education levels based on the industries in which workers of each occupation and education level work. Charts B.4 and B.5 then show the distribution of education levels and occupations across the income distribution.[7]

1 'World Employment Social Outlook 2018 – Greening with Jobs', International Labour Organization (ILO), 2018, p. 42.

2 'The transition in play: Worldwide employment trends in the electricity sector', Geneva, International Labour Organization, Research Department Working Paper No. 28, G. Montt, N. Maitre, S. Amo-Agyei, 2018.

3 'World Employment Social Outlook 2018 – Greening with Jobs', ILO, 2018, p. 42.

4 'Atmospheric emissions: greenhouse gas emissions intensity by industry', 2018 data, ONS, 2020.

5 'Living Costs and Food Survey', ONS, 2014/15-2016/17.

6 These greenhouse gas emissions data record emissions where they occur. They do not account for interdependencies between sectors using outputs that are carbon intensive. For example, many other sector use electricity produced in the electricity and gas sector; however, the carbon associated with the production of electricity is captured in the oil and gas sector rather than passed on to the users of the electricity.

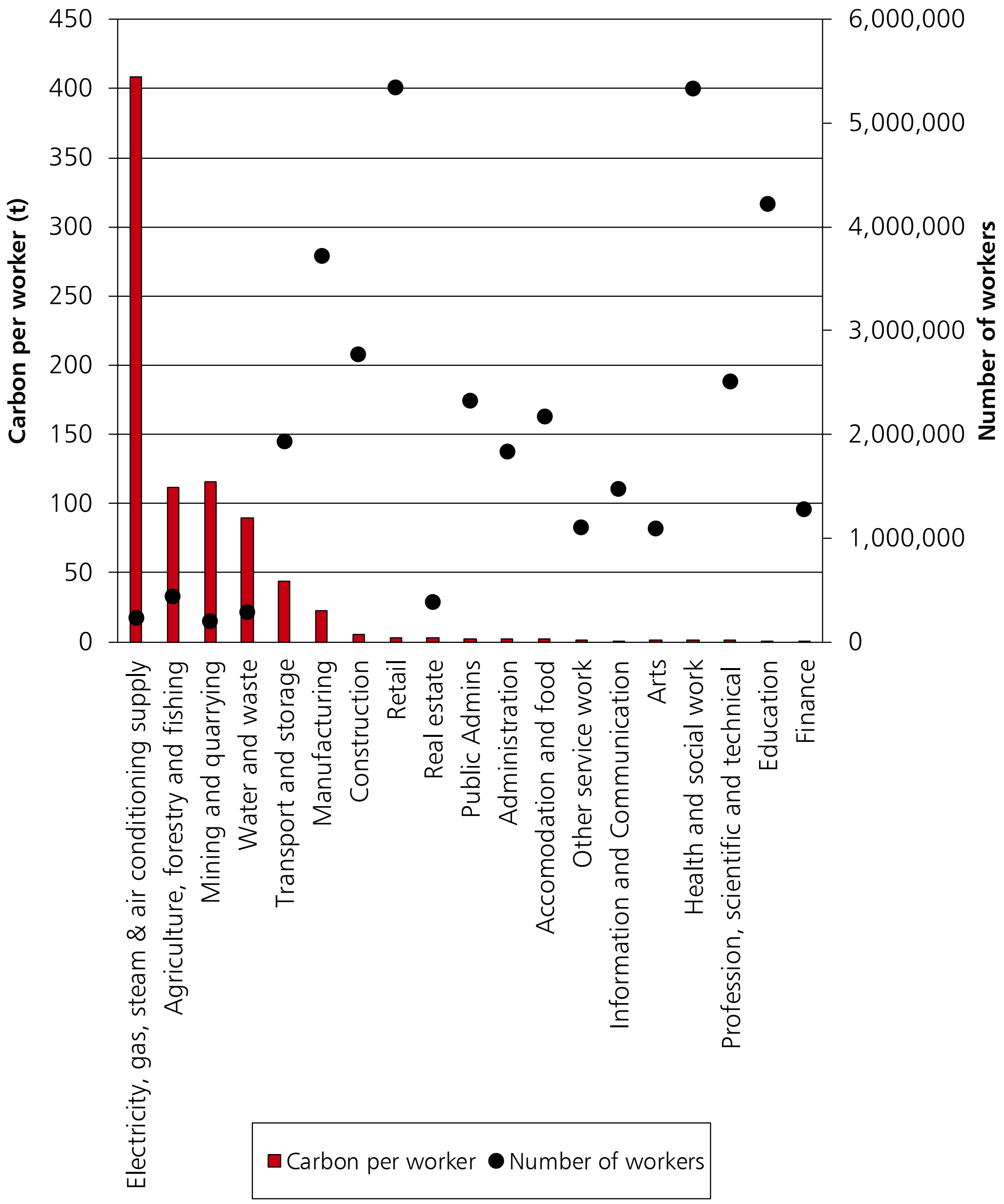
7 Income deciles are defined based on net household income projected in 2020-21.

## Employment by sectoral emissions

B.6 Chart B.1 shows the average carbon intensity per worker by industry. Unsurprisingly, the emissions intensity is highest in the electricity and gas sector – with more than three times the emissions per worker than any other industry. In total, the five industries with the highest carbon intensity contribute more than two-thirds of industrial greenhouse gases, but only employ a fifth of all workers.

B.7 As these sectors decarbonise, the wages and employment opportunities they offer will change, depending on the costs of decarbonising and the policy framework. However, at the same time, there will be growth in lower-carbon sectors. This will create new, competing employment opportunities for people with the skills currently employed in more carbon-intensive sectors.

### Chart B.1 Average carbon per employee by industry




*Source: HM Treasury calculations, LCF household survey, ONS atmospheric emission by industry.*

## Employment, skill types and emissions

B.8 Many workers can perform similar jobs in a number of different industries with very different carbon exposures. To more accurately identify which workers might be more exposed to current carbon use in a dynamic labour market Charts B.2 and B.3 show an average carbon intensity for people in different occupations and skill types. This is calculated based on the sector in which workers from each education level or occupation are currently employed. This assumes that all types of roles within each sector are equally affected by the exposure to carbon.

B.9 Skilled trade, and process plant and machine workers tend to be employed in the most carbon-intensive jobs, reflecting higher employment rates in the agriculture and electric and gas sectors. Process plant and machine workers have a higher carbon intensity due to a higher propensity to work in the transport and storage industry, while skilled trade workers are disproportionately likely to work in the agriculture sector.

B.10 Similarly, people with low and middle levels of education (those with education up to A-levels) tend to be employed in jobs with an average carbon intensity over 20% more than highly educated employees (degree and above).

B.11 During the transition, new, lower-carbon industries and jobs will emerge. The UK's low carbon industries already support over 460,000 jobs,[8] from electric vehicle manufacturing in the Midlands and the North East to the offshore wind industry in the Humber and the Tees. As discussed in Chapter 2 of the Net Zero Review interim report, increasing offshore wind could support 60,000 jobs. Some of these jobs will replace jobs in high carbon sectors, and some will be additional. However, the transition will still require employers to change their practices to reduce their carbon emissions, which may disproportionately affect these occupations and skills levels. The £315 million Industrial Energy Transformation Fund helps such sectors in the UK to decarbonise. The eventual impact on households will depend on the match between the skills in the jobs lost and the jobs created.

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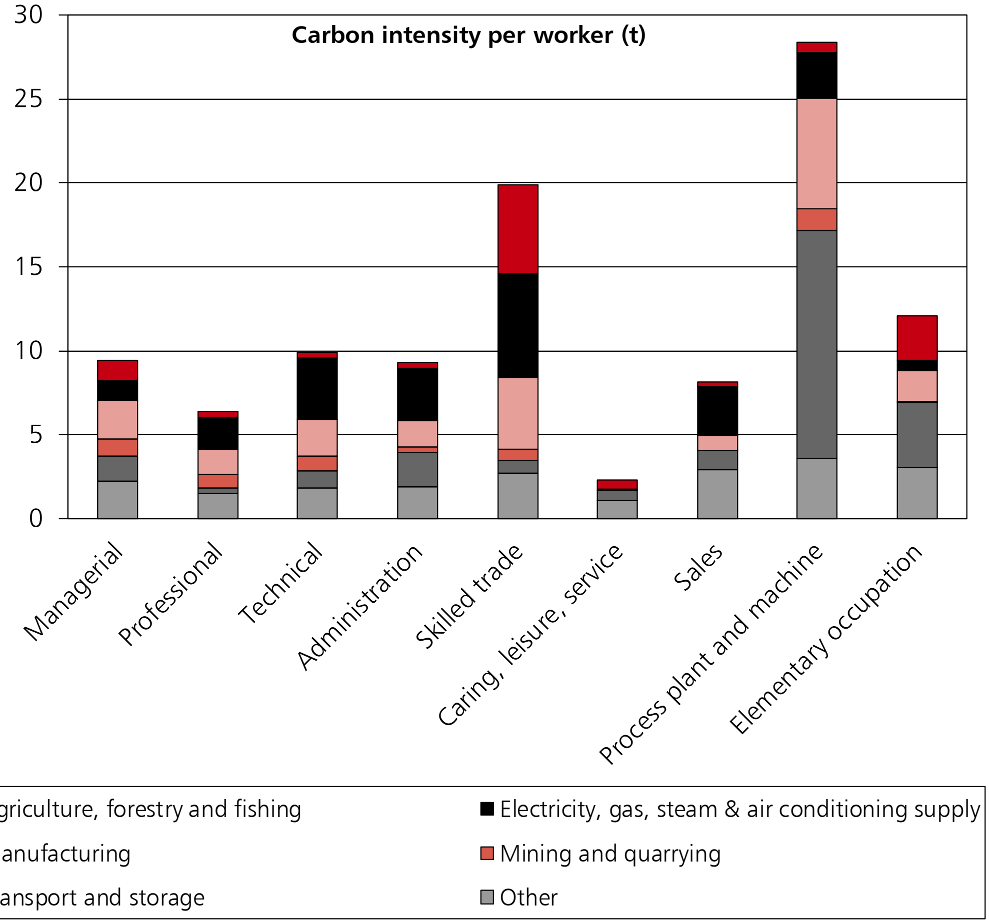
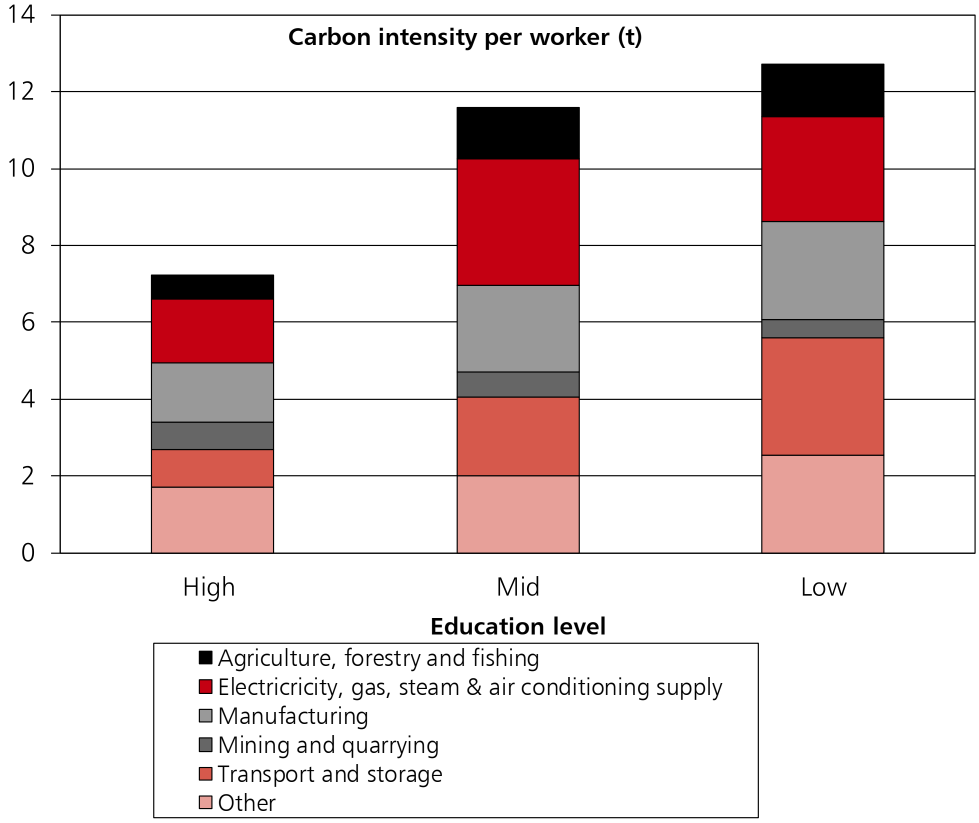
8 'Low Carbon and Renewable Energy Economy (LCREE) Survey QMI', ONS, 2019

## Chart B.2 Average carbon per worker by occupation (based on industry of employment)




*Source: HM Treasury calculations, LCF household survey, ONS atmospheric emission by industry.*

## Chart B.3 Average carbon per worker by education (based on industry of employment)[a]




*Source: HM Treasury calculations, LCF household survey, ONS atmospheric emission by industry.*

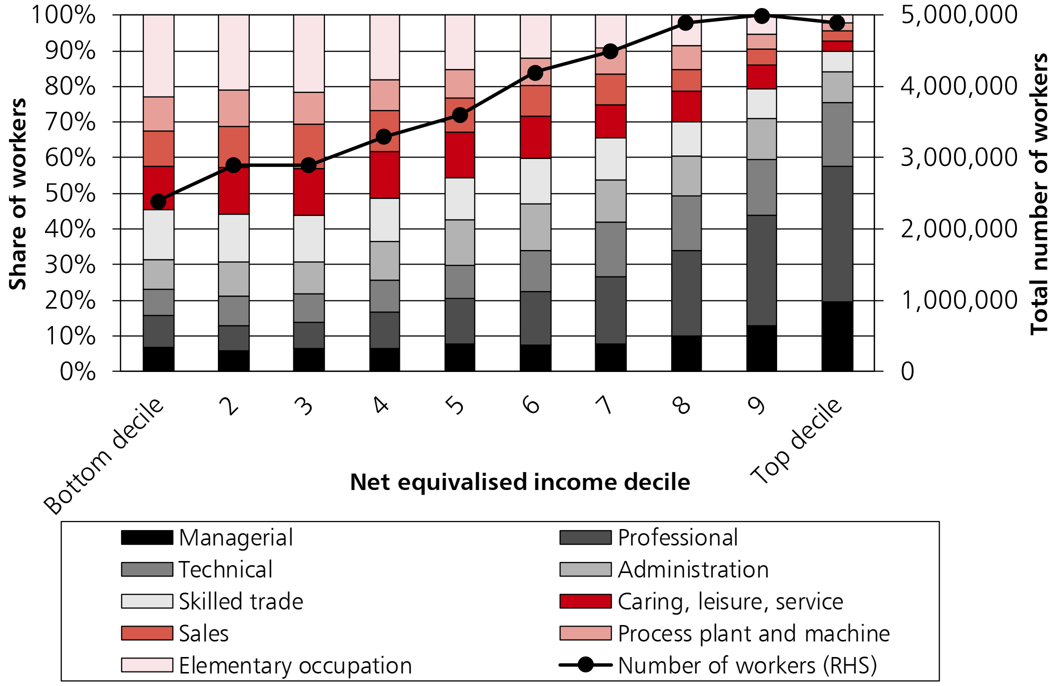
a 'High' education refers to degree level and above, 'Mid' refers to A levels or equivalent, 'Low' refers to GCSE and below.

## Employment, income and emissions

B.12 The final step is to explore the types of households in these employment groups with higher carbon intensity. Chart B.4 shows occupations of employees broken down by net household income decile (lower income households tend to have fewer or no workers and so fewer workers make up the lower deciles). The high carbon intensity occupations, skilled trade, and process plant and machine workers are skewed towards lower-income households: almost a quarter of workers in the lowest income quintile of households work in these occupations compared to one in ten of those from the richest quintile. Similarly, Chart B.5 shows low- and mid-education employees are disproportionately drawn from low-income households.

B.13 However, this does not mean the labour market adjustment would have an overall regressive pattern. Higher-income households receive a significantly greater share of income from earnings, whereas lower-income households receive a greater share of income from welfare. This means that higher-income households are more exposed to any labour market shock. The carbon-specific trends highlighted here are not enough to outweigh this. It is also possible that the carbon intensity of the labour market is geographically concentrated.

## Chart B.4 Distribution of occupations of employees across income deciles




*Source: HM Treasury calculations, LCF household survey, ONS atmospheric emission by industry.*

## Chart B.5 Distribution of education levels of employees across income deciles[a]


*Source: HM Treasury calculations, LCF household survey, ONS atmospheric emission by industry.*

a 'High' education refers to degree level and above, 'Mid' refers to A levels or equivalent, 'Low' refers to GCSE and below.

# Annex C
# Embedding the review

C.1 The transformation required for net zero will mean wide-ranging changes across the economy and across society. Achieving this will be a collective effort from households, businesses and the government. HM Treasury has therefore reviewed its governance, capabilities and processes to support this transition. This annex sets out they key activities underway across HM Treasury in order to support the net zero transition.

## Table C.1: Embedding climate change considerations across HM Treasury

| | Activity | Outline | Timeline |
|---|---|---|---|
| Governance | Establishing a new cross-department Climate Board | As the government's economic and finance ministry, HM Treasury is responsible for maintaining control over key policy levers such as taxation and public spending, setting the direction of the UK's economic policy, and working to achieve strong and sustainable economic growth. Climate change mitigation considerations touch on these responsibilities and will do so increasingly as the UK moves towards net zero. In recognition of this, HM Treasury has established new governance arrangements to align work across different functions so that departmental activities are strategically coherent and complementary on net zero. For example, the Climate Board will help to ensure strategic decisions on tax are made alongside decisions on other levers. | Complete |
| Capacity | Creating a new Climate, Energy and Environment Directorate | HM Treasury has established a new directorate for Climate, Energy and Environment. This will increase capacity on analysis and coordinate climate policy across HM Treasury.<br>As part of this, building on the work of the Net Zero Review team, a standalone, expanded climate team has been established. It will lead HM | Complete |

| | | | |
|---|---|---|---|
| | | Treasury's work on net zero, working together with teams across the department that already contribute to climate policy development and analysis. | |
| Capabilities | Building macroeconomic modelling capability | As outlined in this report, net zero is expected to lead to significant structural changes to the UK economy. Understanding the nature and scale of these changes and the potential impact of policy choices will be vital as government manages the transition to a net zero economy. HM Treasury is therefore committed to continuing to build the necessary modelling capabilities to develop further its understanding of the transition to net zero.<br><br>Macroeconomic modelling tools can help to weigh the complex interactions between the economic channels discussed in this report and gauge the implications for the structure of the economy and to estimate the scale of their macroeconomic impacts.<br><br>Models developed to look at net zero would need to be able to represent:<br><br>**Demand Dynamics**: the model should capture changes in demand particularly the adjustment in consumption and investment<br><br>**Structural Change**: the model should have a detailed sectoral representation in order to capture potential sectoral reallocation in response to changes in the price of carbon<br><br>**Open economy**: in particular changes in competitiveness and the external position of the economy<br><br>The transition to net zero may result in large changes to the economy through various channels and HMT is interested in understanding this transition from different angles, such as the fiscal consequences of economic change. Different models will be better suited to answering the different questions HMT has in a variety of analytical | Ongoing |

| | | | |
|---|---|---|---|
| | | methods and a suite of models will be needed to examine the issue fully.<br><br>HM Treasury will continue to engage with experts in this area as it builds up modelling capacity to ensure it is using international best practice. | |
| Processes | Green Book development, discount rate review and carbon values | The Green Book is HM Treasury's official guidance on appraisal of policies, programmes and projects. It also provides guidance on the design and use of monitoring and evaluation before, during and after implementation. Green Book guidance sets out that all proposals on public spending must consider environment and climate impacts, including greenhouse gas emissions. HM Treasury continues to develop the Green Book and its supplementary guidance so that it is at the forefront of latest evidence including in environmental appraisal. This process is led by HM Treasury and its cross-government Chief Economist Appraisal Group, which oversees developments to the Green Book and its supplementary guidance.<br><br>HM Treasury and the Chief Economist Appraisal Group have supported BEIS in updating supplementary guidance to the Green Book, valuing Greenhouse Gas Emissions (GHG). They are used across government to value changes in GHG emissions resulting from policy interventions. They are also used to support policy design and are an important consideration in policy analysis using the Green Book across departments. This major update has been conducted to reflect the latest evidence and the UK's international and domestic targets, which have led to significant increases in the carbon values used in policy appraisal.[1] | Ongoing |

1 Valuing greenhouse gas emissions in policy appraisal, Department for Business, Energy and Industrial Strategy, September 2021. https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal.

| | | | |
|---|---|---|---|
| | Carbon impacts at fiscal events | There is no internationally adopted methodology for assessing and reporting on the climate change impacts of government spending in aggregate, beyond the project-by-project methodology in the Green Book[2], nor taxation.<br><br>The Public Accounts Committee (PAC) and the National Audit Office (NAO)[3] among other groups have recommended that the UK government should assess the climate impacts of policies at fiscal events. HM Treasury recognises that fiscal events are key opportunities to ensure that climate change is appropriately prioritised in decision-making.<br><br>Spending reviews assess departmental spending bids for the medium-term (generally 3-5 years unless there are exceptional circumstances). HM Treasury then allocates high-level departmental budgets for that specified time period. At Spending Review 2020, HM Treasury guidance required departments to include the likely greenhouse gas emissions generated by bids, and their impact on meeting Carbon Budgets and net zero. HM Treasury is currently reviewing this exercise and these issues will remain at the forefront of HM Treasury's priorities for this year. Having this information will help to improve oversight of the effect of government policies on reducing emissions. In turn, this means that the climate impacts of spending policy can shape decision-making. This will support the government to meet its net zero target at minimum cost to the economy while maximising wider benefits.<br><br>It is also important to further understand, where relevant, the carbon impacts of tax changes. At March Budget 2021, HM Treasury published | Ongoing |

[2] Some classifications such as Rio Markers (OECD) and COFOG classification of spending (INSEE/Eurostat) exist but few methods are comprehensive.

[3] https://www.nao.org.uk/report/achieving-net-zero/

| | | | |
|---|---|---|---|
| | | environmental assessments for relevant environmental tax changes, such as the Plastic Packaging Tax. HM Treasury will be carefully considering next steps in this area. HMRC is exploring options to further strengthen the analytical approach to monitoring, evaluating and quantifying the environmental impacts of tax measures, including their wider impacts. | |
| | Supporting net zero innovation at fiscal events | A technology framework, as outlined in the interim report, can improve understanding of novel and emerging net zero technologies in an uncertain environment. The framework could be used to assess the spread of government support across technology levels, and whether its risk appetite is appropriate to support innovation for the UK's net zero goal. The framework is designed to work alongside existing processes, such as spending reviews and HM Treasury's Green Book, to ensure that HM Treasury's net zero spending is reconciled with its value for money responsibilities. An illustrative example of the use of the framework for SR20 is given in Box B.1 below. | Ongoing |
| | Balance Sheet Review | The public sector balance sheet shows what the government owns and what it owes at a fixed point in time. Since 2017 the government has increased its focus on the management of the public sector balance sheet including undertaking a Balance Sheet Review (BSR). The BSR aimed to identify opportunities to dispose of assets that no longer service a policy purpose, improve returns on retained assets and reduce risks and costs of liabilities.<br>The BSR demonstrates that the government is focused on improving value for money for taxpayers and overall management of assets and liabilities. A concluding report[4] was published alongside the Spending | Ongoing |

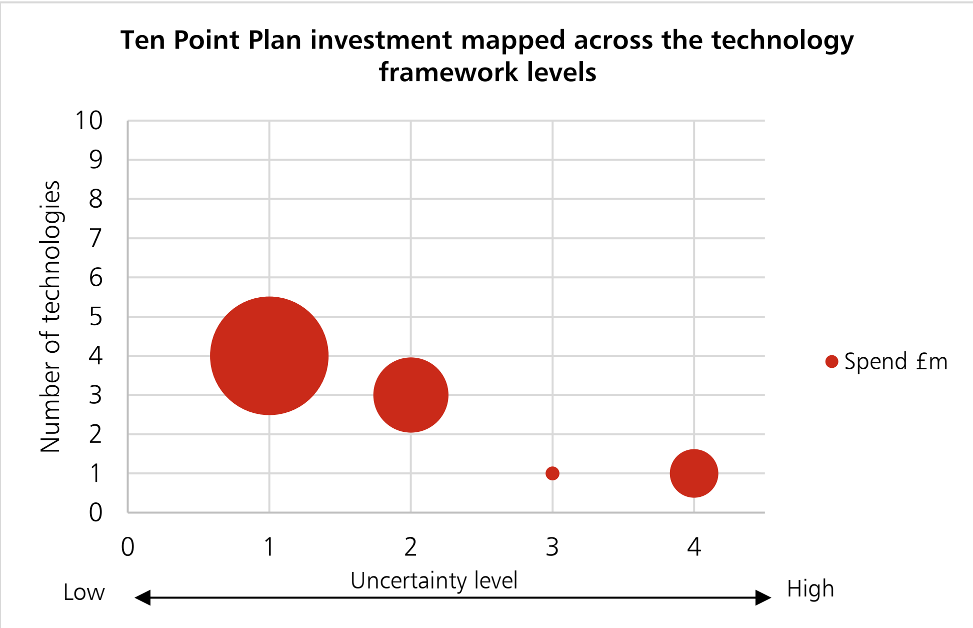
[4] 'The Balance Sheet Review Report: Improving public sector balance sheet management', HM Treasury, 2020.

Review in November 2020 and the report sets out a framework for balance sheet management to help guide future balance sheet interventions.

Currently, the likely impacts of climate change on the government's assets and liabilities are not estimated on the balance sheet. One of the next steps of the BSR is to review the public sector balance sheet and risk exposures in the context of climate change and the shift to a greener economy.

## Box C.1: Illustrative example of the technology framework applied to the Ten Point Plan for a Green Industrial Revolution

The technology framework is aimed to support government decision making with novel and emerging net zero technologies in an uncertain environment. It could be used to assess the spread of government support across technology levels, and consider the spread of risk to support innovation for the UK's net zero goal. For example, public expenditure in the Ten Point Plan mapped against the technology framework illustrates that government is investing across the four uncertainty levels and is taking a mixed approach to investment.



The government is investing where the market cannot provide efficiently without government intervention, such as research related to decarbonisation (level 4).

In priority areas, there is funding in the early stages of deployment to increase the affordability of technologies and move innovations along the technology adoption curve (level 3); these investments are likely to be smaller in scale given the nature of the activity. In the Ten Point Plan this funded investment into Jet Zero and Green ships.

Financial support is being provided where there is significant uncertainty for investors or barriers to entry and scale for new net zero technologies, such as in low carbon hydrogen (level 2). The Ten Point Plan announced funding for an extra £200 million to create two carbon capture clusters by the mid-2020s, with another two set to be created by 2030

Public investment is also supporting the coordination of market actors, for example to leverage further private finance for new large-scale infrastructure or lower the cost of capital, such as with offshore wind or zero emission vehicles (level 1). The Ten Point Plan funded £160 million of investment to modernise ports and manufacturing infrastructure to support the offshore wind industry.

*Source*: *HMT Treasury calculations*

# Annex D
# Engagement

D.1 HM Treasury considered all evidence submitted to it and heard a diverse range of views. The following sections set out various structured engagement channels over the course of the review. This engagement helped to inform the work of the Review, the interim report and this final report. The final report does not necessarily reflect the views of any individual or organisation listed here.

## Bilateral meetings

D.2 The Net Zero Review team engaged with environmental NGOs, consumer groups and other organisations across civil society, academia, and industry across all nations. As part of this, every organisation that requested a meeting on topics relevant to the Review's focus met the team at least once.

Aldersgate Group
Alpenglow
APPG Bankers
Arup
Aurora Energy Research
Australian Government
Aviva
Bank of England
Baxi
British Chambers of Commerce
British Business Bank
British Property Federation
Broadway Initiative
Brunswick Group
Calor Gas
Cambridge Econometrics
Cambridge Zero
Carbon Engineering
Cardiff University EV Project
Confederation of Business Industry
Climate Change Committee
Centre for Sustainable Energy
Centrica
CF Fertilisers
Chatham House
Chrysaor
Citizens Advice
CLA
Climate Coalition
Coalition of Finance Ministers
Committee on Fuel Poverty
Council for Sustainable Business
CREDS
Decarbonised Gas Alliance
Deloitte
Drax
E3G
Energy and Climate Intelligence Unit
EDF Energy
Emissions Trading Group
Energy Futures Group
Energy Systems Catapult
Energy UK
EON
EV Association Northern Ireland
Federation of Small Businesses (Scotland; Northern Ireland; Wales)
Foundation for Tech and Science
Frontier Economics
Future of Engineering
Green Finance Institute
Ground Source Heat Pump Association
Global Infrastructure Investor Association
Greater London Authority

Goldman Sachs
Grantham Institute - LSE
Grantham Institute - Imperial
Green Alliance
Greenpeace
Hydrogen Taskforce
Impact Investing
Institute of Civil Engineers
Institute for Fiscal Studies
Independent Generators Group
Institute for Government
International Monetary Fund
Institute of Directors (Scotland)
Institute for New Economic Thinking
Institute for Public Policy Research
John Hopkins University
Kensa Heatpumps
King's College London
Liebreich Associates
Liquid Gas UK
London Business School
Make UK
Massachusetts Institute of Technology
Mott MacDonald
National Audit Office
National Grid
New Economics Foundation
National Farmers Union
Octopus Renewables
Oil and Gas UK
Ovo
London School of Tropical Hygiene
Policy Exchange
Prince of Wales Corporate Leaders Group
PwC
Quadrature Climate Foundation
Retail Motor Industry Federation
Resolution Foundation
Ricardo
Rolls Royce
Royal Society for the Protection of Birds
Sitra
Scottish Power
Scottish Cities Alliance
Shell
Social Market Foundation
SSE
Sustainability First
Tech UK
The Association of Decentralised Energy
The Foundation for Science and Technology
The National Institute of Economic and Social Research
The Royal Society
Treasury Select Committee
Trades Union Congress
University College London
UK Finance
UK Green Building Council
UKREC
UK Regulators Network
University of Cambridge [Christ's College, Cambridge Centre for Environment, Energy and Natural Resource Governance]
University of Edinburgh [Energy and Society]
University of Exeter [Energy Policy]
University of Leeds
University of Oxford [Oxford Smith School, Department of Physics, Institute for New Economic Thinking, Oxford Martin School]
University of Strathclyde
US Delegation
Which?
Whitehall Industry Group
Zero Carbon (ZeroC)

## Advisory groups

D.3 The Net Zero Review set up two external Advisory Groups to provide proactive comment and constructive challenge on key areas. Members were invited based on their expertise. They were not paid, and potential conflicts of interests were declared.

D.4 The Economics of Decarbonisation Advisory Group was made up of leading experts in climate change economics to provide insight and challenge to the analysis produced by the Net Zero Review. The members of the Group were invited in a personal capacity to comment on work as it progressed, without obligation on either parties to agree the content of the interim or final reports.

### Table D.1: Economics of Decarbonisation Advisory Group

| | |
|---|---|
| Professor Laura Diaz Anadon | Professor of Climate Change Policy, University of Cambridge |
| Professor Sir Dieter Helm CBE | Professor of Economic Policy, University of Oxford |
| Paul Johnson CBE | Director, Institute for Fiscal Studies |
| Baroness Nemat Minouche Shafik | Director, London School of Economics |
| Professor Lord Nicholas Stern | Professor Economics and Government, and Chair, Grantham Research Institute on Climate Change and the Environment, London School of Economics |
| Lord Adair Turner | Chair of the Energy Transitions Commission |

D.5 The Technology and Innovation Advisory Group focused on investment and innovation. The aim was to stress test HM Treasury's analysis and emerging thinking. Members were invited to provide feedback and additional evidence to support discussions. There was no obligation on members to agree the content of the Net Zero Review's interim or final reports.

### Table D.2: Technology and Innovation Advisory Group

| | |
|---|---|
| Johan Eliasch | Chair; President of the International Ski Federation; Chairman HEAD; and, former Special Representative of the Prime Minister of the United Kingdom on Deforestation and Clean Energy |
| Professor Sam Fankhauser | Professor of Climate Change Economics and Policy, University of Oxford |
| Professor Catherine Mitchell | Professor of Energy Policy, University of Exeter |
| Dervilla Mitchell CBE | Member of PM's Council for Science and Technology; Chair of the National Engineering Policy Centre's Net Zero emissions working group; Deputy Chair, Arup Group |

| | |
|---|---|
| Nick Molho | Director, Aldersgate Group |
| Philip New | CEO, Energy Systems Catapult |
| Professor Nick Robins | Professor in Practice - Sustainable Finance, Grantham Institute, London School of Economics |
| Dr Emily Shuckburgh OBE | Director, Cambridge Zero, University of Cambridge |
| Dr Rhian-Mari Thomas OBE | Chief Executive, Green Finance Institute |
| Eliot Whittington | Director, The Prince of Wales' Corporate Leaders Group |

## Net Zero Review interim report

D.6 The Net Zero Review interim report was published in December 2020. The report set out initial analysis and an outline of the areas the Review would focus on ahead of the final report. It invited feedback and comments on the published analysis, with a designated mailbox for written submissions.

D.7 It received 40 written responses ranging across environmental organisations, industry and other groups, with more informal feedback received in meetings. Though the interim report was not a consultation nor a call for evidence, the feedback was valuable. Overall, the comments were positive about the analysis. They focused primarily on the wider benefits from net zero, the uncertainties involved in quantifying the costs of the net zero transition, and the role of public engagement.

## Themed roundtables

D.8 HM Treasury held three themed roundtables, convening experts and industry specialists on: investment in innovation and infrastructure; electric vehicles; and, heat and buildings. The objectives were to gather evidence and gain expert insight, as well as test initial analysis.

### Table D.3: Themed roundtables

| Roundtable | Participants |
|---|---|
| Investment in innovation and infrastructure | **Chair:** Exchequer Secretary to the Treasury<br>**Attendees:** Aviva; BlackRock; Bloomberg New Energy Finance; Green Finance Institute; Investment Association; Johan Eliasch; Standard Life Aberdeen; and, Zouk Capital. |
| Electric vehicles | **Chair:** Niva Thiruchelvam<br>**Attendees:** Autotrader; British Vehicle Rental and Leasing Association; Citizens Advice; CLA; EDF; Energy Savings Trust; Green Finance Institute; Finance and Leasing Association; Nissan; Office for Zero Emissions Vehicles; The |

| | |
|---|---|
| | Society of Motor Manufacturers and Traders; Which?; and, Zap-Map. |
| Heat and buildings | **Chair:** Niva Thiruchelvam<br>**Attendees:** Barclays; British Property Federation; Citizens Advice; CLA; Energy Saving Trust; Engie; Eon; Green Finance Institute; National Energy Action; Nationwide; Parity Projects/Ecology Building Society; Resolution Foundation; and, UK Finance. |

## HM Treasury contacts

This document can be downloaded from www.gov.uk

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