

Title: Impact Assessment for the sixth carbon budget IA No: BEIS012(F)-21-CG RPC Reference No: N/A Lead department or agency: Department for Business, Energy and Industrial Strategy Other departments or agencies:	Impact Assessment (IA)			
	Date: 16/04/2021			
	Stage: Final			
	Source of intervention: Domestic			
	Type of measure: Secondary legislation			
Contact for enquiries: Dennis Morgan (Dennis.Morgan@beis.gov.uk)				
Summary: Intervention and Options				RPC Opinion: Not Applicable

Cost of Preferred (or more likely) Option (in 2019 prices)			
Total Net Present Social Value	Business Net Present Value	Net cost to business per year	Business Impact Target Status
£266bn	£0m	£0m	Not a regulatory provision

What is the problem under consideration? Why is government intervention necessary?

There is overwhelming scientific consensus that we are living with the effects of significant global climate change, driven predominantly by anthropogenic greenhouse gas (GHG) emissions. Global action is needed to mitigate the potentially catastrophic impact of climate change across the world, and to help secure the UK's long-term economic security. Action to limit emissions would not happen at sufficient scale without government intervention, as the costs are not fully factored into private decisions. In 2019, the government amended the Climate Change Act to set a net zero target in law, for 2050. The UK has also committed to the 2015 Paris Agreement, which affirms the global ambition to keep the increase in global average temperature to well below 2°C above pre-industrial levels, and to pursue efforts to limit the temperature increase to 1.5°C.

What are the policy objectives of the action or intervention and the intended effects?

The Climate Change Act requires the government to set the sixth carbon budget as a limit on the net UK carbon account over 2033-37. The Act requires this level must be set with a view to reducing emissions to net zero by 2050. The objective now is to set the level of the budget, with proposals on how the budget is met to be published as soon as reasonably practical thereafter.

What policy options have been considered, including any alternatives to regulation? Please justify preferred option (further details in Evidence Base)

There is no alternative to the legal requirement in the Climate Change Act to set a sixth carbon budget level with a view to reducing UK emissions to net zero by 2050. The following options for the level of the budget have been considered, including a 'do nothing' option where no further emission reduction measures are pursued (for comparison purposes only) and also the level recommended by the independent Climate Change Committee (Option 3):

- Option 1 (Do nothing): 2100 million tonnes of carbon dioxide equivalent (MtCO₂e)
- Option 2: 1105 MtCO₂e;
- Option 3: 965 MtCO₂e;
- Option 4: 885 MtCO₂e.

Will the policy be reviewed? Evidence will be refreshed in 2026 when setting the seventh carbon budget.¹

Is this measure likely to impact on international trade and investment?	No			
Are any of these organisations in scope?	Micro Yes	Small Yes	Medium Yes	Large Yes
What is the CO ₂ equivalent change in greenhouse gas emissions? (Million tonnes CO ₂ equivalent)	Total: 6434 MtCO ₂ e			

I have read the Impact Assessment and I am satisfied that, given the available evidence, it represents a reasonable view of the likely costs, benefits and impact of the leading options.

Signed by the responsible Minister of State for Business, Energy and Clean Growth Anne-Marie Trevelyan Date: 19/04/2021

¹ The Climate Change Act also contains a mechanism for amending a carbon budget after it has been set, if it appears to the Secretary of State that significant changes have taken place that affect the basis on which the budget was set.

Summary: Analysis & Evidence

Policy Option 1

Description: A 'do-nothing' budget of 2100MtCO_{2e}, which likely requires no new emission reductions

FULL ECONOMIC ASSESSMENT

Price Base Year 2019	PV Base Year 2020	Time Period Years 30	Net Benefit (Present Value (PV)) (£m)			
			Low: Optional	High: Optional	Best Estimate: £0m	
COSTS (£m)	Total Transition (Constant Price) Years		Average Annual (excl. Transition) (Constant Price)		Total Cost (Present Value)	
Low	Optional		Optional		Optional	
High	Optional		Optional		Optional	
Best Estimate	£0		£0		£0	
Description and scale of key monetised costs by 'main affected groups'						
There are no abatement costs associated with this option as it is estimated under most reasonable "business as usual" emissions scenarios that the UK net carbon account will remain within this budget level. However, this level is not consistent with meeting the UK's net zero 2050 target.						
Other key non-monetised costs by 'main affected groups'						
N/A						
BENEFITS (£m)	Total Transition (Constant Price) Years		Average Annual (excl. Transition) (Constant Price)		Total Benefit (Present Value)	
Low	Optional		Optional		Optional	
High	Optional		Optional		Optional	
Best Estimate	£0		£0		£0	
Description and scale of key monetised benefits by 'main affected groups'						
There are no benefits associated with this option as it is estimated under most reasonable emissions scenarios that the UK net carbon account will remain within this budget level.						
Other key non-monetised benefits by 'main affected groups'						
N/A						
Key assumptions/sensitivities/risks					Discount rate	3.5
This would undermine the credibility of UK action on climate change and send negative signals to investors in low carbon technologies.						

BUSINESS ASSESSMENT (Option 1)

Direct impact on business (Equivalent Annual) £m:			Score for Business Impact Target (qualifying provisions only) £m:
Costs: £0	Benefits: £0	Net: £0	
			£0

Summary: Analysis & Evidence

Policy Option 2

Description: Looser budget option of 1105MtCO_{2e}, in line with CCC's Headwinds scenario

FULL ECONOMIC ASSESSMENT

Price Base Year 2019	PV Base Year 2020	Time Period Years 30	Net Benefit (Present Value (PV)) (£m)		
			Low: Optional	High: Optional	Best estimate: £289,000

COSTS (£m)	Total Transition (Constant Price) Years		Average Annual (excl. Transition) (Constant Price)	Total Cost (Present Value)
Low	Optional		Optional	Optional
High	Optional		Optional	Optional
Best Estimate	£0		£37,400	£589,000

Description and scale of key monetised costs by 'main affected groups'

The main costs considered are for deploying additional emissions abatement technologies relative to option 1. These include, but are not limited to, costs of low carbon technologies, supporting infrastructure, finance, and fuel (including bioenergy). Some costs of increased air quality pollutants are also monetised. An illustrative breakdown by sectors of the economy shows that the majority of costs are associated with reducing emissions from surface transport, buildings and power. The distribution of costs between affected groups will depend on future policy decisions.

Other key non-monetised costs by 'main affected groups'

Some risks to natural capital, social and wider economic circumstances are considered qualitatively.

BENEFITS (£m)	Total Transition (Constant Price) Years		Average Annual (excl. Transition) (Constant Price)	Total Benefit (Present Value)
Low	Optional		Optional	Optional
High	Optional		Optional	Optional
Best Estimate	£0		£61,100	£879,000

Description and scale of key monetised benefits by 'main affected groups'

Carbon savings, monetised using government carbon values, are the main benefit. Also included are reduced damage costs of air quality pollutants, some natural capital benefits and operational savings where fuel costs are reduced. Benefits are only considered at a societal level and a distributional breakdown is not considered.

Other key non-monetised benefits by 'main affected groups'

Some natural capital benefits have been considered qualitatively, such as benefits to biodiversity. Potential wider economic impacts of decarbonisation are also considered, such as improvements to innovation, competitiveness, and export opportunities.

Key assumptions/sensitivities/risks

3.5

The portfolio of policies to deliver the budget level is unconfirmed at this stage, though the analysis presented gives a sense of the challenges. The monetisation of emissions reduction measures is provided as an illustration only, and is based on knowledge of theoretically achievable options, which are assumed to be deliverable from a technical perspective. Emissions savings are valued using the High Carbon Values series, with the Central series tested as a sensitivity. High and low fuel costs and GDP projections are also tested as sensitivities. National damage costs are used to value air quality impacts. As a sensitivity, the impact of removing the wealth element of the social discount rate for emissions savings is tested.

BUSINESS ASSESSMENT (Option 2)

Direct impact on business (Equivalent Annual) £m:			Score for Business Impact Target (qualifying provisions only) £m:
Costs: £0	Benefits: £0	Net: £0	
			£0

Summary: Analysis & Evidence

Policy Option 3

Description: The CCC's recommended budget level at 965MtCO_{2e}

FULL ECONOMIC ASSESSMENT

Price Base Year 2019	PV Base Year 2020	Time Period Years 30	Net Benefit (Present Value (PV)) (£m)		
			Low: Optional	High: Optional	Best estimate: £266,000

COSTS (£m)	Total Transition (Constant Price) Years		Average Annual (excl. Transition) (Constant	Total Cost (Present Value)
Low	Optional		Optional	Optional
High	Optional		Optional	Optional
Best Estimate	£0		£41,200	£651,000

Description and scale of key monetised costs by 'main affected groups'

The main costs considered are for deploying additional emissions abatement technologies relative to option 1. These include, but are not limited to, costs of low carbon technologies, supporting infrastructure, finance, and fuel (including bioenergy). Some costs of increased air quality pollutants are also monetised. An illustrative breakdown by sectors of the economy shows that the majority of costs are associated with reducing emissions from surface transport, buildings and power. The distribution of costs between affected groups will depend on future policy decisions.

Other key non-monetised costs by 'main affected groups'

Some risks to natural capital, social and wider economic circumstances are considered qualitatively.

BENEFITS (£m)	Total Transition (Constant Price) Years		Average Annual (excl. Transition) (Constant	Total Benefit (Present Value)
Low	Optional		Optional	Optional
High	Optional		Optional	Optional
Best Estimate	£0		£63,700	£918,000

Description and scale of key monetised benefits by 'main affected groups'

Carbon savings, monetised using government carbon values, are the main benefit. Also included are reduced damage costs of air quality pollutants, some natural capital benefits and operational savings where fuel costs are reduced. Benefits are only considered at a societal level and a distributional breakdown is not considered.

Other key non-monetised benefits by 'main affected groups'

Some natural capital benefits have been considered qualitatively, such as benefits to biodiversity. Potential wider economic impacts of decarbonisation are also considered, such as improvements to innovation, competitiveness, and export opportunities.

Key assumptions/sensitivities/risks	Discount	3.5
<p>The portfolio of policies to deliver the budget level is unconfirmed at this stage, though the analysis presented gives a sense of the challenges. The monetisation of emissions reduction measures is provided as an illustration only, and is based on knowledge of theoretically achievable options, which are assumed to be deliverable from a technical perspective. Emissions savings are valued using the High Carbon Values series, with the Central series tested as a sensitivity. High and low fuel costs and GDP projections are also tested as sensitivities. National damage costs are used to value air quality impacts. As a sensitivity, the impact of removing the wealth element of the social discount rate for emissions savings is tested.</p>		

BUSINESS ASSESSMENT (Option 3)

Direct impact on business (Equivalent Annual) £m:			Score for Business Impact Target (qualifying provisions only) £m:
Costs: £0	Benefits: £0	Net: £0	
			£0

Summary: Analysis & Evidence

Policy Option 4

Description: Tighter budget option at 885MtCO_{2e}, in line with CCC's widespread innovation scenario

FULL ECONOMIC ASSESSMENT

Price Base Year 2019	PV Base Year 2020	Time Period Years 30	Net Benefit (Present Value (PV)) (£m)		
			Low: Optional	High: Optional	Best Estimate: £211,000

COSTS (£m)	Total Transition (Constant Price) Years	Average Annual (excl. Transition) (Constant Price)	Total Cost (Present Value)
Low	Optional	Optional	Optional
High	Optional	Optional	Optional
Best Estimate	£0	£45,000	£725,000

Description and scale of key monetised costs by 'main affected groups'

The main costs considered are for deploying additional emissions abatement technologies relative to option 1. These include, but are not limited to, costs of low carbon technologies, supporting infrastructure, finance, and fuel (including bioenergy). Some costs of increased air quality pollutants are also monetised. An illustrative breakdown by sectors of the economy shows that the majority of costs are associated with reducing emissions from surface transport, buildings and power. The distribution of costs between affected groups will depend on future policy decisions.

Other key non-monetised costs by 'main affected groups'

Some risks to natural capital, social and wider economic circumstances are considered qualitatively.

BENEFITS (£m)	Total Transition (Constant Price) Years	Average Annual (excl. Transition) (Constant Price)	Total Benefit (Present Value)
Low	Optional	Optional	Optional
High	Optional	Optional	Optional
Best Estimate	£0	£64,300	£936,000

Description and scale of key monetised benefits by 'main affected groups'

Carbon savings, monetised using government carbon values, are the main benefit. Also included are reduced damage costs of air quality pollutants, some natural capital benefits and operational savings where fuel costs are reduced. Benefits are only considered at a societal level and a distributional breakdown is not considered.

Other key non-monetised benefits by 'main affected groups'

Some natural capital benefits have been considered qualitatively, such as benefits to biodiversity. Potential wider economic impacts of decarbonisation are also considered, such as improvements to innovation, competitiveness, and export opportunities.

Key assumptions/sensitivities/risks

Discount rate

3.5

The portfolio of policies to deliver the budget level is unconfirmed at this stage, though the analysis presented gives a sense of the challenges. The monetisation of emissions reduction measures is provided as an illustration only, and is based on knowledge of theoretically achievable options, which are assumed to be deliverable from a technical perspective. Emissions savings are valued using the High Carbon Value series, with the Central series tested as a sensitivity. High and low fuel costs and GDP projections are also tested as sensitivities. National damage costs are used to value air quality impacts. As a sensitivity, the impact of removing the wealth element of the social discount rate for emissions savings is tested.

BUSINESS ASSESSMENT (Option 4)

Direct impact on business (Equivalent Annual) £m:			Score for Business Impact Target (qualifying provisions only) £m:
Costs: £0	Benefits: £0	Net: £0	
			£0

Table of Contents

Executive Summary	7
1 Introduction and framework.....	15
1.1 Context	15
1.2 Framework for decision.....	17
1.3 Uncertainties and risks.....	19
1.4 Accounting and scope.....	20
1.5 International Aviation and Shipping (IAS)	21
1.6 Counterfactual and baseline – “do nothing” option	22
1.7 The sixth carbon budget levels and pathways to 2050	23
1.8 Public sector equality duty	24
2 Analysis.....	26
2.1 Evidence base	26
2.2 Technical feasibility of sixth carbon budget levels.....	27
2.3 Delivery Implications	35
2.4 International circumstances	38
2.5 Quantified cost and benefits	45
2.6 Unquantified cost and benefits - Section 10 and 13 impacts	49
3 Conclusion	59
Annexes.....	62
A.1 Assumptions.....	62
A.2 UK TIMES model	63
A.3 GLOCAF model and fair-share pathway methodology	68
A.4 Supplementary evidence base	70
A.5 Natural capital.....	72
A.6 Accounting for Devolved Administrations’ views and characteristics.....	76

Executive Summary

Introduction

1. The Climate Change Act requires Parliament to set the level of the sixth carbon budget, covering the five year period 2033 to 2037, with a view to meeting the target of reducing the UK's net greenhouse gas (GHG) emissions by at least 100% ("net zero") by 2050.
2. There is overwhelming scientific consensus that we are living with the effects of significant global climate change, driven primarily by anthropogenic GHG emissions. Unchecked this will lead to rising temperatures and sea levels, extreme weather, damaged ecosystems, and reduced productivity of crops. Coordinated global action is needed to substantially reduce GHG emissions and mitigate the potentially catastrophic effects of climate change on the environment and economies across the world.
3. Setting long-term targets to reduce GHG emissions will also help to secure long-term economic security and prosperity, globally and in the UK. While there is inherent uncertainty around estimates of the long-term impact of climate change, at global level it is clear that the cost of inaction is much higher than the cost of action. Without government intervention individual efforts to mitigate climate change are unlikely to be sufficient.
4. When setting carbon budgets, the government must take account of the advice of the Climate Change Committee (CCC). The CCC recommends the sixth carbon budget is set at 965MtCO_{2e}, implying a 78% reduction in emissions from 1990 to 2035. The government has conducted its own analysis, based on our own analytical assumptions, which includes consideration of this recommended budget level. Our assessment of this overall budget level is separate from our consideration of the CCC's policy recommendations to achieve the emissions abatement needed to meet the budget. The budget must also be set with a view to complying with the UK's wider international obligations, and accounting for any representations of the Devolved Administrations.
5. The Impact Assessment concludes that **the CCC's recommended option for the sixth carbon budget level is the preferred option**, which best supports the UK's policy objective to substantially reduce GHG emissions and brings significant benefits for society. This Impact Assessment does not put forward the government policies needed to meet the different sixth carbon budget options. It presents an illustrative assessment of possible pathways through the sixth carbon budget period to 2050, recognising the uncertainty whilst still allowing an assessment of the key costs, benefits, risks and opportunities of different budget levels.
6. The government will publish the Net Zero Strategy later this year, setting out its vision for transitioning to a net zero economy. This will build on the Prime Minister's Ten Point Plan for a Green Industrial Revolution and ambitious plans across key sectors of the economy. These sectoral plans include the Energy White Paper published last December, the Industrial Decarbonisation Strategy published in March, as well as the Transport Decarbonisation Plan, Hydrogen Strategy and Heat and Buildings Strategy to be published shortly.

Analytical approach

7. The analysis presents illustrative pathways to 2050, rather than forecasts or predictions. There is a great deal of uncertainty inherent in such analysis. In particular:
 - we are not able to account for potential or as yet unknown future structural changes to the economy, such as shifts in behavioural patterns after the COVID-19 pandemic, future macro-economic developments, or substantial changes in consumer preferences;
 - there is considerable uncertainty around the future of technologies, both in terms of the development and costs of existing known technologies and also the impact of unknown technological innovations.
8. These uncertainties will likely lead to different outcomes than the illustrative analysis presented in this Impact Assessment. However, the sensitivity analysis and range of factors considered provide a solid evidence base for making a decision on the level of the sixth carbon budget.
9. The CCC advise that the budget should be set on the basis of territorial UK emissions; inclusive of emissions from international aviation and shipping (IAS) and wetlands; and using evidence on global warming potentials of GHGs from the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report. We have accepted this advice and all options for the sixth carbon budget considered are presented on this basis.
10. Apart from the "do nothing" option, the analysis assumes that all emissions pathways to 2050 meet existing UK commitments. This includes the UK's Nationally Determined Contribution (NDC) to reduce emissions by at least 68% by 2030 compared to 1990 (excluding IAS emissions), which is more ambitious than the fifth carbon budget covering 2028-32. The analysis also assumes emissions decline linearly from the end of the sixth carbon budget to reach the legislated target of net zero emissions by 2050. Not all costs and benefits presented are additional to current government ambition or policy plans, but this does not impact the *relative* difference in costs and benefits between options for the sixth carbon budget.
11. Four options are considered, including a 'do nothing' baseline:

Table 1: Shortlisted sixth carbon budget level options

	Description	Sixth carbon budget level (MtCO _{2e})	Reduction in 2035 from 1990 ¹
Option 1	Do Nothing Baseline (non-binding sixth carbon budget)	2100	53%
Option 2	Looser budget option (in line with CCC's 'headwinds' scenario)	1105	75%
Option 3	CCC's recommend budget	965	78%
Option 4	Tighter budget option (in line with CCC's 'widespread innovation' scenario)	885	80%

¹ 1990 comparison uses the 1990-2019 GHG Inventory and assumptions on the impact of forthcoming changes to GHG estimates for long-term targets. UK GHG emissions estimates are revised annually to incorporate methodological improvements, updated data and changes to international guidelines. The percentage reductions are therefore subject to change.

Assessment of options

12. The Impact Assessment analyses the different options based on a holistic framework fulfilling the requirements of the Climate Change Act across five criteria. The findings are summarised below.

1) Long-term pathways and technological feasibility

13. This criterion focuses on the extent to which the different options are consistent with least-cost technology mixes in 2050, including what they imply for reliance on uncertain technologies or maximum feasible build rates. It should be noted, however, that the cost-optimal technology and energy mix is more affected by the uncertainty arising from technology and resource availability than by the choice of the sixth carbon budget level.
14. The analysis indicates that all options apart from 'do nothing' can be considered consistent with net zero in 2050 and are technically feasible, even without some of the changes in consumer demand included in the CCC's analysis (e.g., changing diets to reduce demand for meat and dairy).
15. Options 2-4 are challenging and technically stretching. They require at least doubling current electricity generation by 2050 and rely on substantial hydrogen production and biomass use, although the final energy mix is highly sensitive to modelling assumptions. If the UK were to keep options open on the path to net zero by 2050, then by 2035 any option for the sixth carbon budget will entail:
- significant electrification of sectors such as transport, heating and industry, and continued decarbonisation of the power grid;
 - substantially improved energy efficiency in all sectors;
 - deployment of low-carbon hydrogen, Carbon Capture and Storage (CCS) and GHG removal technologies at scale;
 - increased switching to low-carbon fuels (e.g., hydrogen, biomass) in hard to electrify areas such as industry, heavy transport, aviation and shipping;
 - implementation of available abatement options across all natural resources sectors (e.g. afforestation, low carbon farming practices).
16. Increasing ambition from Option 2 to 3 (CCC recommended level) has limited effect on land-use, agriculture, and engineered removals of emissions as feasible cost-effective abatement is already exhausted in these sectors in Option 2. Electrification over the sixth carbon budget period increases by around 13% in Option 3 compared to Option 2. However, high use of hydrogen for heating by 2050 still remains feasible with additional effort in other sectors (e.g., land use and transport) to offset slower decarbonisation in buildings (as widescale hydrogen heating is unlikely to be available by the mid-2030s). Sectors pushed further in Option 3, indicating higher marginal costs, include surface transport, fuel supply, industry, and buildings. The tightest budget level considered, Option 4, involves going even further in the transport, industry, fuel supply and buildings sectors, stretching technical feasibility and potentially leading to non-economical outcomes in transport.

2) Delivery implications

17. This criterion focuses on the delivery barriers and challenges that apply to a range of possible pathways. It does not consider the specific policy mix for each option, given the government's policies to meet the sixth carbon budget have not yet been determined.
18. All options but 'do nothing' would require substantial additional effort across each sector of the economy, beyond existing government plans. Consumers and producers will need to change the technologies they use, and in many cases the up-front costs of low carbon technologies, such as heat pumps, are currently higher than the technologies they replace. Supply chains for low carbon technologies will need to be significantly scaled up and, in some cases, need to be demonstrated before they can move to wider-scale deployment. Government intervention will be needed to overcome a broad range of barriers, including technical, market, behavioural and socio-political. In addition to maximising market-led decarbonisation, strengthening regulation is likely to be necessary in some cases.
19. As the policies required to meet the sixth carbon budget levels have not yet been determined, it is not possible to analyse the precise difference in the level of barriers of the different options. However, it is expected that the marginal policies required to meet more ambitious budget options will be more challenging.

3) International circumstances

20. This criterion considers UK action in the context of global efforts to reduce emissions and honouring the UK's international commitments. The UK will host COP26 later in 2021, which aims to accelerate global action towards achieving Paris Agreement temperature goals.
21. The budget options are compared against benchmark emissions under different interpretations of global mitigation effort shares in '1.5°C' and 'well below 2°C' scenarios. All options apart from 'do nothing' are more ambitious than if global mitigation efforts were shared across countries or regions on the basis of estimates of cost-effective technical abatement potential. However, they are less ambitious than if efforts were shared with historical contributions to emissions taken into account.
22. The budget options are also compared against global average emissions in pathways that are aligned with the Paris Agreement's climate change mitigation ambition. All options apart from 'do nothing' deliver emission reductions on a per capita basis that, if followed globally, would be consistent with the global ambition to keep the increase in global average temperature in line with the Paris Agreement's temperature goal. Relative to Option 2, Options 3 and Option 4 would fare more favourably from a global climate leadership perspective by delivering faster emission reductions and resulting in lower cumulative emissions to 2050. Although there is uncertainty, the different trajectories lead to different outcomes, and looser pathways, all else being equal, will lead to higher global temperature, higher risks of extreme events or require greater reliance on GHG removal technologies in the long-term to meet the Paris Agreement's temperature goal.

4) Quantified costs and benefits

23. This criterion quantifies as many costs and benefits as possible related to the level of the sixth carbon budget. The long-lived nature of technologies means many of these costs and benefits occur before the sixth carbon budget period begins and endure after it has

ended. Moreover, the level of the sixth carbon budget will have a large bearing on the overall pathway to net zero in 2050. The appraisal therefore considers costs and benefits over the period from 2020 to 2050. However, the cost-benefit analysis should not be seen as a full appraisal of the UK's decision to achieve net zero by 2050. It is not exhaustive: it does not, for example, quantify potential industrial opportunities or transition risks, which will depend on how the budget is delivered, and wider co-benefits such as health outcomes.

24. The majority of quantified benefits are emissions savings, with fossil fuel savings, air quality improvements and other natural capital impacts constituting the remaining benefits. Non-carbon benefits do not differ significantly between options. The large majority of costs are the additional capital costs (and associated financing) of low carbon technologies. Significant fuel savings are expected, offsetting 20% of additional capital costs. It is estimated that the net cost (excluding air quality and emissions savings benefits) of meeting the CCC's recommend sixth carbon budget level will be equivalent to 1.6% of GDP in 2035.
25. Options 2 to 4 have significantly positive net present values (NPVs), with quantified benefits more than offsetting the costs. Results are sensitive to modelling assumptions – most notably, the NPVs increase in a high Carbon Capture and Storage (CCS) scenario and decrease if CCS were delayed. Less ambitious options have marginally higher NPVs than more ambitious levels, indicating that the marginal cost of abatement is higher than government's current high carbon values. However, differences between options are small in percentage terms: for example, the NPV for Option 2 is £23bn higher than Option 3 in the core pathway, a difference of 9%.
26. There is considerable uncertainty around NPV estimates, especially while the policies to meet the budget are not confirmed. For example, tighter budget levels could have the potential to increase the rate of technology cost reductions (particularly those where cost reduction is driven by UK rather than global deployment), and also increase the value of additional exports of UK low carbon technologies. There is also, however, a possibility that the UK could benefit from cost reductions driven by technological deployment in other countries which choose to decarbonise faster, balanced against the risk that less action from the UK would slow global efforts and so result in higher costs for all.
27. Increased climate ambition can foster innovation that increases domestic competitiveness and provides potential export opportunities for some sectors. But there will also be risks to competitiveness, particularly for sectors that are trade-exposed or carbon intensive, and these risks are greater if the UK's climate ambition continues to exceed that of trading partners. Other countries could also benefit from earlier UK investment and cost reduction in key technologies, which could help support global decarbonisation but presents potential risks to UK competitiveness that would have to be managed.

5) Unquantified costs and benefits and wider impacts

28. As it is not possible to quantify all costs and benefits, this criterion considers wider impacts, and ensures full consideration of the factors required by Section 10 of the Climate Change Act. Factors considered here in additional detail include scientific knowledge; economic (in particular, the likely impact of the decision on the economy and the competitiveness of certain sectors of the economy), fiscal and social circumstances;

energy policy; the views of Devolved Administrations; and environmental impacts such as natural capital. Many of the wider, non-quantifiable impacts do not change significantly under different options and depend heavily on how government chooses to deliver the budget.

29. Climate science highlights huge risks to people and the environment if global temperatures exceed 1.5°C, and uncertainties around projections make worst-case scenarios real and dangerous possibilities. The options imply only minor differences in future UK cumulative emissions which represents a very small fraction of global emissions. However, if the UK can influence more ambitious targets from other countries this could meaningfully contribute to global efforts towards net zero.
30. When delivering the sixth carbon budget, the wider environmental impacts of the policy mix will need to be taken into account to ensure trade-offs are managed and impacts mitigated. For example, meeting the sixth carbon budget will require significant and competing demands for land, resulting in large changes to its use and management.
31. The views of the Devolved Administrations have also been taken into account, all of which are supportive of the CCC's recommended level (Option 3).

Conclusion

32. Considering all assessment criteria in the round, including specific factors set out in the Climate Change Act, **the proposed option for the sixth carbon budget level is 965MtCO_{2e}, Option 3**. This option is the recommended level by the CCC and the preferred option of the Devolved Administrations. The high level of ambition supports the overall policy objective of mitigating the potentially catastrophic effects of climate change, while the more ambitious Option 4 could lead to non-economical outcomes. Option 3 is more challenging than Option 2 from a technical feasibility and delivery perspective, but the analysis shows it is technically feasible to achieve and has a strongly positive NPV. Option 3 is also in line with an ambitious contribution to global efforts towards meeting the Paris Agreement temperature goal and strengthens the UK position in pushing for higher ambition from other countries. Whilst the costs of this option are higher and the NPV is smaller than those of Option 2, these relative differences are within the uncertainty ranges and in the whole outweighed by the other assessment criteria.
33. The following sections present the full evidence base supporting these conclusions. The table below provides a summary of the criteria considered for each budget level option.

Table 2: Summary of the assessment criteria across the different options

Consideration	Budget level option			
	Option 1	Option 2	Option 3	Option 4
Budget level (in MtCO _{2e})	2100	1105	965	885
CCC advice	Highly insufficient to meet the CCC's balanced pathway to Net Zero.	In line with CCC's <i>headwinds scenario</i> and less ambitious than the recommended balanced pathway.	CCC recommended level.	In line with CCC's <i>widespread innovation scenario</i> and more ambitious than the recommended level.
Devolved Administration views	Not consistent with DA views	Not consistent with DA views	Budget level endorsed by all DAs	Scottish Government view Option 3 as minimum appropriate ambition
Assessment criteria				
1) Long-term pathways and technological feasibility	Budget is technically feasible, but the pathway does not meet the UK's 2050 target and is inconsistent with the 2030 NDC.	Budget is challenging and technically stretching but feasible and in line with the 2050 target.	Budget is technically feasible and in line with the 2050 target, but more stretching and more technically challenging than Option 2.	Budget is technically feasible, but more technically challenging than Option 3 and might lead to non-economical outcomes.
2) Delivery implications	No delivery implications , as no additional abatement action beyond current policies necessary.	Budget is stretching to deliver with barriers of all types to overcome.	Budget is more challenging to deliver than Options 2 and more reliant on overcoming barriers.	Budget is more challenging to deliver than Option 3 and more reliant on overcoming barriers.
3) International circumstances	Insufficient to deliver the UK's international ambition.	Budget is consistent with Paris Agreement temperature goal.	Budget is consistent with Paris Agreement temperature goal; likely to be perceived as internationally ambitious by delivering faster emission reductions and resulting in lower cumulative emissions than Option 2.	Budget is consistent with Paris Agreement temperature goal; likely to be perceived as very internationally ambitious by delivering faster emission reductions and resulting in lower cumulative emissions than Option 3.

Consideration	Budget level option			
	Option 1	Option 2	Option 3	Option 4
Budget level (in MtCO ₂ e)	2100	1105	965	885
4) Quantified cost & benefits				
Indicative NPV of core scenario 2020-2050 (£bn, 2019), range shown in brackets	0	289 (176-330)	266 (127-292)	211 (67-249)
Composition of NPV:				
Costs of core scenario 2020-2050 (Present Value, £bn, 2019)	0	589 (554-710)	651 (622-775)	725 (693-865)
Benefits of core scenario 2020-2050 (Present Value, £bn, 2019)	0	879 (873-886)	918 (896-918)	936 (927-941)
5) Unquantified costs and benefits and wider impacts	<p>With the right policies, there is potential for greater economic benefits for the tighter budget options, such as innovation and export opportunities.</p> <p>Those factors that must be considered under the Climate Change Act that are not covered above (climate change science, economic, social and fiscal circumstances, energy policy) are summarised in table 21.</p>			

1 Introduction and framework

34. This Impact Assessment supports the government's decision on the level of the UK's sixth carbon budget, a limit on the amount of UK greenhouse gas emissions (GHGs) over the period 2033-2037. This introductory section provides background, including details on the Climate Change Act ("the Act") and the UK's role in tackling the global challenge of anthropogenic climate change, as well as introducing the decision framework, the scope of the considered budget and the Climate Change Committee's (CCC) advice on the level of the sixth carbon budget.²

1.1 Context

35. The government introduced the Climate Change Act in 2008, including a 2050 target and supporting framework of carbon budgets, to ensure the UK makes an appropriate contribution to limiting global warming. A carbon budget places a legally binding restriction on the net UK carbon account over a five-year period.
36. The first five carbon budgets covering the period 2008 to 2032 have already been set in law. The Climate Change Act requires Parliament to set the level of the sixth carbon budget, covering 2033 to 2037, by 30th June 2021. This limits the amount of net UK GHG emissions, adjusted for any credits/debits of international emissions credits.
37. The Climate Change Act specifies that the level of the sixth carbon budget must be set with a view to meeting the target of reducing net UK emissions by at least 100% ("net zero") by 2050. The budget must also be set with a view to complying with the UK's wider international obligations. The UK has also committed to the 2015 Paris Agreement, which affirms the global ambition to keep the increase in global average temperature to well below 2°C above pre-industrial levels, and to pursue efforts to limit the temperature increase to 1.5°C. In setting the level of the sixth carbon budget the government must take into account the advice of the CCC and any representations of the Devolved Administrations.
38. Once the sixth carbon budget is set in legislation, the Act requires the government to publish a report on the policies and proposals to deliver the budget (and those carbon budgets up to this point) 'as soon as is reasonably practicable' thereafter. As details of policies and proposals to meet the sixth carbon budget are still being finalised, this Impact Assessment considers, at a high level, the illustrative impacts of meeting different budget levels. It does not make specific assumptions on how the sixth carbon budget will be delivered, including the policy recommendations put forward by the CCC in their sixth carbon budget advice.

The Climate Change Committee's advice on the sixth carbon budget

39. The CCC is an independent statutory body that advises the UK and devolved administration governments on setting and meeting carbon budgets and preparing for climate change. Under section 34 of the Act the CCC must advise on: the level of each carbon budget; the extent to which the carbon budget should be met through reducing net UK emissions or through the purchase of carbon units from overseas; and the respective contributions that different sectors should make; and in doing so it must take into account certain matters specified under the Act (section 10).
40. The CCC published its advice on the sixth carbon budget on 9th December 2020. It recommends that the sixth carbon budget be set at 965MtCO_{2e}, implying a 78%

² CCC 6th Carbon Budget Advice: <https://www.theccc.org.uk/publication/sixth-carbon-budget/>

reduction in emissions from 1990 to 2035. The CCC recognise that this target would achieve well over half of the required emissions reductions required from 2020 to 2050 in the next 15 years – implying an average annual reduction of 21MtCO_{2e} between 2019 and 2035, compared to 13MtCO_{2e} between 2035 and 2050. The CCC advise that the budget should be set on the basis of territorial UK emissions; inclusive of emissions from international aviation and shipping (IAS) and wetlands; and using the Intergovernmental Panel on Climate Change’s (IPCC) Fifth Assessment Report Global Warming Potentials (see section 1.4 on accounting and scope). The CCC also advise that the budget should be met without purchase of international credits.

41. While the CCC’s advice also makes recommendations on how to meet the sixth carbon budget level, this Impact Assessment does not set out how the sixth carbon budget will be delivered. The government will set out its own delivery plan with policies in line with its own priorities and assumptions. In modelling options, this analysis also makes different assumptions in some areas to the CCC – notably, the CCC’s analysis includes some changes in consumption patterns that are not modelled here. For example, this analysis does not assume a shift in people’s dietary patterns. The full portfolio of policies to deliver the budget level is not decided at this stage, though the analysis does give a sense of the challenge.

Existing carbon budgets

42. The fifth carbon budget was set in 2016, before the 2050 target was changed to net zero in 2019. The CCC have advised that, while their recommended trajectory to net zero in 2050 implies emissions will have to fall more quickly than required by the existing carbon budgets (i.e. the fourth and fifth, covering 2023-27 and 2028-32), it is not necessary to amend the existing budget levels in legislation. The CCC consider that the advised sixth carbon budget level, combined with the UK’s NDC (which commits the UK to reducing emissions by at least 68% by 2030, compared to 1990 levels³) would set the UK on the path to net zero, but it is for the government to decide whether the existing budgets should be amended.
43. The government does not consider it necessary to amend the level of any existing carbon budgets in legislation. The 2030 NDC and the proposed sixth carbon budget put the UK on track for net zero by 2050 and will necessarily entail overachieving on the 5th carbon budget. This analysis assumes that the UK will achieve the reduction in emissions needed to meet its 2030 NDC. The level of each of the first five carbon budgets are shown in the table below.

Table 3: Level of existing carbon budgets

	First carbon budget (2008-2012)	Second carbon budget (2013-2017)	Third carbon budget (2018-2022)	Fourth carbon budget (2023-2027)	Fifth carbon budget (2028-2032)
Legislated carbon budgets (MtCO_{2e})	3,018	2,782	2,544	1,950	1,725
Equivalent percentage reduction from 1990 levels⁴	26%	31%	37%	52%	58%

³ NDC excludes IAS emissions: /www.gov.uk/government/publications/the-uks-nationally-determined-contribution-communication-to-the-unfccc

⁴ Percentage reductions are indicative based on latest estimates of base year emissions (812 MtCO_{2e}) from the UK 1990-2019 GHG Inventory. <https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2019> (table 2.1). Carbon Budget base year emissions are calculated as emissions of CO₂, CH₄ and N₂O in 1990, and fluorinated gases in 1995. Base year emissions and equivalent percentage reductions are subject to change following annual changes to GHG emissions estimates in the GHG Inventory. This is not the same base year used to calculate the percentage reduction of the sixth carbon budget option (see paragraph 37).

Policy objective

44. There is overwhelming scientific consensus that we are living with the effects of significant global climate change, driven predominantly by anthropogenic GHG emissions. Unchecked this leads to rising temperatures and sea levels, extreme weather, damaged ecosystems, and reduced productivity of crops. Coordinated global action is needed to rapidly reduce GHG emissions and reach net zero, and so mitigate the potentially catastrophic effects of climate change on the environment and economies across the world, while ensuring that action also supports wider environmental sustainability, such as water quality and availability of raw materials.
45. Setting long-term targets to reduce GHG emissions will also help secure long-term economic security and prosperity, globally and in the UK. While there is inherent uncertainty around estimates of the long-term impact of climate change, it is clear that at the global level the cost of inaction is much higher than the cost of action, as set out in the Stern Review⁵ and the Impact Assessment for the Climate Change Act. GHG emissions are a global externality and emitters do not directly face the consequences of their actions or take these consequences fully into account when taking decisions. This is because climate change is global in both its causes and consequences; its impacts are long-term and persistent; there are few markets for GHG emissions and there are substantial uncertainties and risks over their economic impacts. As a result, without government intervention individual efforts to mitigate climate change are unlikely to reduce emissions on a sufficient scale.

1.2 Framework for decision

46. This Impact Assessment considers four levels for the sixth carbon budget, as shown in table 4. Three options have been selected to reflect an appropriate range of budget levels that are consistent with the 2030 NDC target and the 2050 Net Zero target. They include the CCC recommended budget level (Option 3), a higher budget level (Option 2) that is in line with the CCC's 'headwinds' scenario and a lower budget level that is in line with the CCC's 'widespread innovation' scenario (Option 4). All three options are compared to a 'do-nothing' baseline scenario based on the latest BEIS energy and emissions projections (see paragraph 33) (Option 1).

Table 4: Shortlisted sixth carbon budget level options

	Description	Sixth carbon budget level (MtCO _{2e})	Reduction in 2035 from 1990 ⁶
Option 1	Do Nothing Baseline (non-binding sixth carbon budget)	2100	53%
Option 2	Looser budget option (in line with CCC's 'headwinds' scenario)	1105	75%
Option 3	CCC's recommend budget	965	78%
Option 4	Tighter budget option (in line with CCC's 'widespread innovation' scenario)	885	80%

⁵ Stern, N. (2007). *The Economics of Climate Change: The Stern Review*. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511817434

⁶ For the purpose of this analysis, base year (1990) emissions of 887MtCO_{2e} are assumed. This is on the accounting basis set out in section 1.4. Baseline uses 1990-2019 GHG Inventory and assumptions on the impact of forthcoming changes to GHG estimates for long-term targets. UK GHG emissions estimates are revised annually to incorporate methodological improvements, updated data and changes to international guidelines. The percentage reductions are therefore subject to change.

47. This Impact Assessment assesses options using a holistic assessment framework that fulfils the requirements of the Climate Change Act across five assessment criteria. Section 10(2) of the Act requires the Secretary of State to take into account a non-exhaustive list of relevant matters when coming to a decision on setting a carbon budget. Of these matters, several can be quantified in detail, and are taken into account as part of consideration of criteria (1) – (4) below. Other matters are harder to quantify, and so are considered as ‘wider impacts’ in criterion (5). For completeness and to ensure compliance with the statutory framework, criterion (5) works through all of the section 10(2) factors, even where some have also been considered under earlier criteria.

1) Long-term pathways and technological feasibility

48. This criterion draws on both whole-system modelling and sector-specific evidence to identify different pathways that meet the UK’s 2050 Net Zero target. This ensures that the decision on the sixth carbon budget is not taken in isolation but in context of the UK’s long-term climate change target. Using the results of the long-term pathways and additional evidence on delivery challenges, this criterion assesses the extent to which least-cost technology mixes under the different carbon budget levels are consistent with least-cost mixes in 2050. It also considers the extent to which different options imply reliance on uncertain technologies or maximum feasible technology build rates.

2) Delivery implications

49. Feasibility of delivery is assessed at a high-level: this Impact Assessment does not consider specific pathways to meeting the sixth carbon budget levels, nor a specific set of policies. Instead, the delivery challenge is discussed by exploring barriers and challenges that apply to a range of possible policies and pathways.

3) International circumstances

50. This considers the sixth carbon budget level options in the context of global efforts to reduce GHG emissions and the commitments taken by the UK at an international level, including the Paris Agreement and the United Nations Framework Convention on Climate Change (UNFCCC). As part of the UNFCCC process, the UK successfully bid to assume the Presidency in 2021 of the 26th Conference of the Parties (COP26), which aims to accelerate global action towards achieving the Paris Agreement temperature goals. This section includes an assessment of what UK action could be considered cost-effective, fair and equitable under different global warming scenarios and different interpretations of how to allocate effort shares in global emissions reductions.

4) Quantified costs and benefits

51. This Impact Assessment quantifies as many of the significant cost and benefits of the decision on the sixth carbon budget level as possible. Many of these costs and benefits occur before the sixth carbon budget begins and endure after it has ended. Therefore, in order to provide a complete view, all impacts to 2050 are considered.

5) Unquantified costs and benefits and wider impacts

52. It is not possible to quantify all costs and benefits, as well as wider impacts. Therefore, this criterion assesses these in a qualitative manner. This ensures full consideration of the factors required by section 10 of the Climate Change Act. Factors considered here in additional detail include scientific knowledge; economic (in particular the likely impact of the decision on the economy and the competitiveness of particular sectors of the economy) and fiscal circumstances; social circumstances; energy policy; the views of Devolved Administrations; and environmental impacts such as natural capital.

1.3 Uncertainties and risks

53. There are a large number of uncertainties and risks in forecasting the UK's transition to net zero. Many of these have been considered and quantified throughout the analysis. These include:
- Risks that technologies and resources will not be available as they are currently expected to be. This has been considered through four pathways, which reflect differing assumptions about technology availability and performance for particularly uncertain technologies. It is not possible to fully quantify the technological and resource uncertainty inherent to the net zero transition.
 - Uncertainty over future GDP growth, which impacts emissions and thus changes the level of abatement technology deployment required to reach net zero. This has been considered through testing low and high GDP growth as a sensitivity in the cost benefit analysis.
 - Uncertainty over future fuel prices, which impacts the relative cost of switching to low carbon alternative fuels. This has been considered through testing low and high fuel price assumptions as a sensitivity in the cost benefit analysis.
 - Uncertainty over the social rate of time preference with respect to environmental benefits. This is considered by removing the wealth effect from the standard 3.5% discount rate as a sensitivity in the cost benefit analysis, reflecting the possibility that the value placed by society on the environment is not sensitive to levels of wealth.
 - Uncertainty over baseline emissions projections and accounting standards, such as the global warming potential standard. This has been considered by using high assumptions based on information available at the time which result in the highest projected emissions as currently estimated and which therefore define the highest level of abatement that may be required given current available information.
 - Uncertainty over the emissions reductions required to meet global temperature targets. These have been considered by providing confidence intervals to global emissions pathways where appropriate.
54. Not all identifiable uncertainties and risks have been quantified, but these have been acknowledged where appropriate. These include:
- Uncertainty over the future development and cost profiles of existing technologies, and the impacts of possible technological innovations that do not currently exist, which are not possible to quantify.
 - The risks to delivery associated with policies that will likely be needed to meet the sixth carbon budget. Since this impact assessment is policy neutral, only technical feasibility has been accounted for in quantified analysis, but likely delivery challenges for each sector have been considered.
 - Uncertainties over the future structure of the economy. Structural changes to the economy may include, but are not limited, to changing behaviour, consumption or trade patterns.
 - Uncertainties over global developments in technology, macroeconomy and climate ambition.
 - Uncertainty over the long-term impacts of climate change.

55. This does not represent an exhaustive list of the risks and uncertainties over the UK's transition to net zero.

1.4 Accounting and scope

56. The accounting basis for the sixth carbon budget does not need to be finalised in law until 2039, when the 2037 annual statement of emissions will be published. Depending on future accounting decisions, carbon accounting regulations may be required to establish the applicable accounting framework. When assessing the different options for the sixth carbon budget level, this Impact Assessment has made assumptions about the specific scope and accounting framework for emissions as set out in the sections below.
57. However, the international science behind measuring emissions is continually evolving and the assumptions made here do not therefore preclude future decisions that are still to be made on emissions accounting at both domestic and international level. If future accounting decisions turn out to differ from the assumptions made in this Impact Assessment, this would not automatically lead to a change in the budget level. However, the Climate Change Act allows for legislated carbon budget levels to be amended if the government believes that, since the budget level was originally set, there have been significant changes affecting the basis on which the previous decision was made (Section 21 of the Climate Change Act).

Territorial accounting

58. When setting previous carbon budgets, Impact Assessments followed a net accounting framework that constructed the total carbon budget as a sum of two individual components: i) emissions covered by the EU Emissions Trading System (ETS), known as “traded sector” emissions (around one third of all UK emissions); and ii) emissions outside the EU ETS known as “non-traded sector” emissions. When the UK was part of the EU ETS, the UK share of EU ETS allowances was used to calculate “traded sector” emissions, and emissions in the “non-traded sector” were measured as actually emitted.
59. The UK has now left the European Union and is no longer a part of the EU ETS. A UK Emissions Trading Scheme, which is currently standalone, has been established in its place (although electricity generators in Northern Ireland continue to participate in the EU ETS). The CCC have made their recommendation to set the sixth carbon budget level on a territorial basis, i.e., accounting for all actual emissions occurring within the UK. This Impact Assessment assesses the carbon budget options on the same basis. This does not preclude any future decisions on the UK ETS or future carbon accounting regulations.

Global Warming potential

60. The UK's performance against its climate change targets is measured in terms of tonnes of carbon dioxide equivalents (tCO_{2e}). Emissions of each greenhouse gas covered by the Climate Change Act are expressed in CO_{2e}, recognising the different global warming potentials (GWP) of the different gases. The IPCC have proposed an updated set of GWPs in their Fifth Assessment Report (AR5)⁷, affecting the GWP of methane, nitrous oxide, and some F-gases. This update changes the CO_{2e} of these gases, but there is still uncertainty around whether those values will be adopted internationally with or without carbon-cycle feedbacks. In either case, the values are different from the GWPs used in

⁷ AR5 Synthesis Report: Climate Change 2014, <https://www.ipcc.ch/report/ar5/syr/>

the current UK GHG inventory and it is expected that the updated values or even a subsequent update will be in place by the time of the sixth carbon budget period.

61. To reflect this and ensure that the sixth carbon budget can still be met after these potential changes, the Impact Assessment uses the higher AR5 GWP values, i.e., those with carbon-cycle feedback. Compared to the GWP used in the current UK inventory, this affects the GWP of methane. This does not preclude a decision on which AR5 GWP values will be adopted internationally. The CCC's advice on the sixth carbon budget follows the same approach.

Emissions from peatlands

62. Emissions from peatlands were only partially captured in the UK GHG inventory when the first five carbon budgets were set. A major revision in the inventory was implemented in February 2021 for the 1990-2019 inventory^{8,9} to represent these emissions with methodologies consistent with the IPCC Wetlands Supplement.¹⁰ These emissions remain subject to very large uncertainties. This Impact Assessment is based on the assumptions of the Evans. et al. report (2017).¹¹
63. Overall, assumptions used in this Impact Assessment for peatlands emissions are about 4-5 MtCO_{2e} per year higher than the estimates included in the GHG inventory 1990-2019 (the main differences being a different set of assumptions for forest soils). Taking a higher estimate in this analysis ensures that the sixth carbon budget can be met even in a scenario where peatland emissions are slightly higher than the assumptions currently considered as the most accurate. A similar approach was taken by the CCC in its analysis.

International Carbon Units

64. The Climate Change Act allows the potential for the purchase of International Carbon Units (ICUs) to count against meeting carbon budgets. The Act places a statutory duty upon government to set a limit on the quantity of ICUs that can be used to meet a carbon budget. This ICU credit limit, which caps the net amount of ICUs that can be credited to the net UK carbon account for that budgetary period, must be set in legislation 18 months ahead of the start of each budget. The level of the credit limit provides the extent to which abatement in other countries can be procured in place of abatement in the UK where more cost effective or otherwise beneficial. The CCC recommends "that ICUs should not be used to meet the sixth carbon budget, though they may be useful policy tools or appropriate ways to go beyond the carbon budgets to support global decarbonisation efforts". Noting that any purchase of ICUs is a decision for the future, this analysis only considers domestic action to meet the sixth carbon budget. This does not preclude any future decisions on the use of ICUs.

1.5 International Aviation and Shipping (IAS)

65. To date, international aviation and shipping (IAS) emissions have not been legally included in the UK's carbon budgets, instead leaving 'headroom' for these emissions. The CCC's recommended budget includes emissions from the UK's share of IAS, which

⁸ Planned methodology changes for UK greenhouse gas emissions, 2021, <https://www.gov.uk/government/publications/planned-methodology-changes-for-uk-greenhouse-gas-emissions>

⁹ Final UK greenhouse gas emissions national statistics: 1990 to 2019 <https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2019>

¹⁰ 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, https://www.ipcc.ch/site/assets/uploads/2018/03/Wetlands_Supplement_Entire_Report.pdf

¹¹ Using "Tier 2" emission factors for forestry, https://naei.beis.gov.uk/reports/reports?report_id=980

allows for them to be accounted for consistently with other emissions. We intend to follow this approach and legally include IAS emissions in the sixth carbon budget.

66. The CCC has recommended that the method of including IAS emissions in the sixth carbon budget should be ‘bunker fuel sales’. Under this method, IAS emissions are estimated from refuelling from ‘bunkers’¹² at UK airports and ports, whether by UK or non-UK operators¹³. For the purposes of this Impact Assessment, the estimates of IAS emissions presented below have been aligned with the CCC’s recommended method.

1.6 Counterfactual and baseline – “do nothing” option

67. To frame the appraisal of the options for the level of the sixth carbon budget, the Impact Assessment considers how UK emissions are likely to evolve from now in the absence of any new (and as yet unannounced) policy action to reduce emissions.
68. BEIS publishes projections of emissions and energy demand for the UK on an annual basis. For the purposes of this Impact Assessment the reference scenario from BEIS’s latest emission projections (EEP 2019) published in December 2020¹⁴ has been adjusted for:
- Updated macroeconomic growth assumptions. These have been aligned to the OBR long-term forecasts published in March 2020¹⁵ and the short-term central forecast published in July 2020.¹⁶ The published emissions projections were aligned to March 2019 OBR forecasts.¹⁷
 - Emissions accounting changes. These include AR5 Global Warming Potentials and additional emissions from IAS and wetlands in line with the scope used for the sixth carbon budget in this Impact Assessment.
 - The emissions projections only extend to 2040. Beyond this period they are assumed to grow in line with underlying demand drivers.
69. In terms of policies, the baseline only includes government policies which had been implemented, adopted or planned as of August 2019.¹⁸ These policies are all assumed to be implemented as planned. The baseline does not include more recently announced government policies and ambitions which are yet to be factored into projections, including those policies set out in the PM’s 10 Point Plan for a Green Industrial Revolution¹⁹ and the Energy White Paper.²⁰
70. These adjusted baseline emission projections are compared to the published projections in figure 1. The resulting emissions over the sixth carbon budget period are 2100MtCO₂e, compared with 1725MtCO₂e in the published EEP 2019 reference case.

¹² A large container or compartment that stores fuel for ships or aircraft.

¹³ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957887/2019_Final_greenhouse_gas_emissions_statistical_release.pdf

¹⁴ Updated energy and emissions projections: 2019, www.gov.uk/government/publications/updated-energy-and-emissions-projections-2019

¹⁵ Economic and fiscal outlook, OBR, <https://obr.uk/efo/economic-and-fiscal-outlook-march-2020/>

¹⁶ Fiscal sustainability report, OBR, <https://obr.uk/fsr/fiscal-sustainability-report-july-2020/>. The OBR also published a short-term forecast alongside Spending Review 2020 in November 2020.

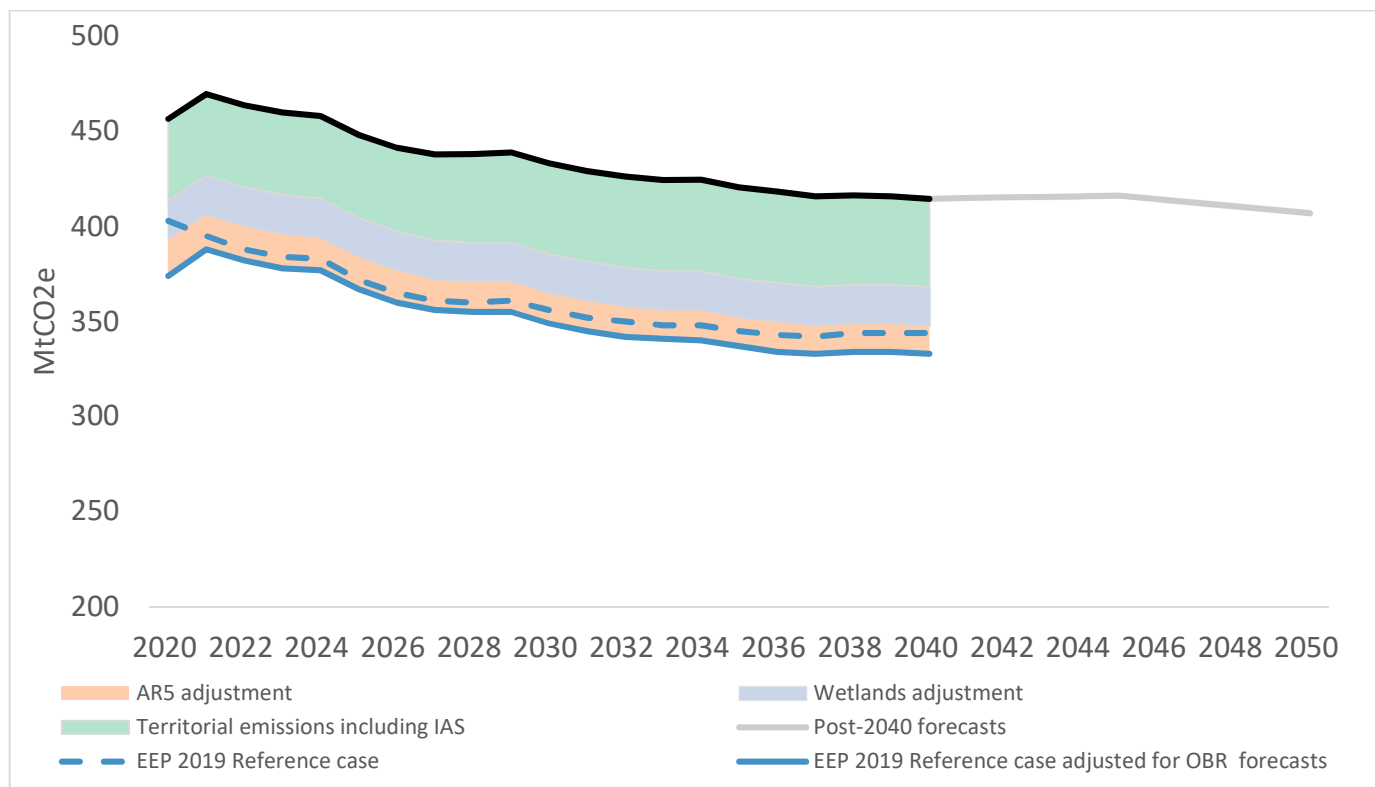
¹⁷ Economic and fiscal outlook, OBR, <https://obr.uk/efo/economic-fiscal-outlook-march-2019/>

¹⁸ Examples of policies announced or in consultation since August 2019 (and hence not included) are the introduction of the Green Home Grant, a consultation on changes to the taxation of red diesel and a green gas levy, and also a consultation on bringing forward the phase-out date for internal-combustion engine sales from 2040, and other measures announced in HMG’s 10 point plan and as part of Spending Review 2020 (e.g. 40GW offshore wind target). If these were included, the projected level of emissions would be lower and the incremental cost of action also lower, however this would not change the relative assessment of options considered in this Impact Assessment.

¹⁹ The ten point plan for a green industrial revolution, 2020, <https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution>

²⁰ Energy white paper: Powering our net zero future, 2020, www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future

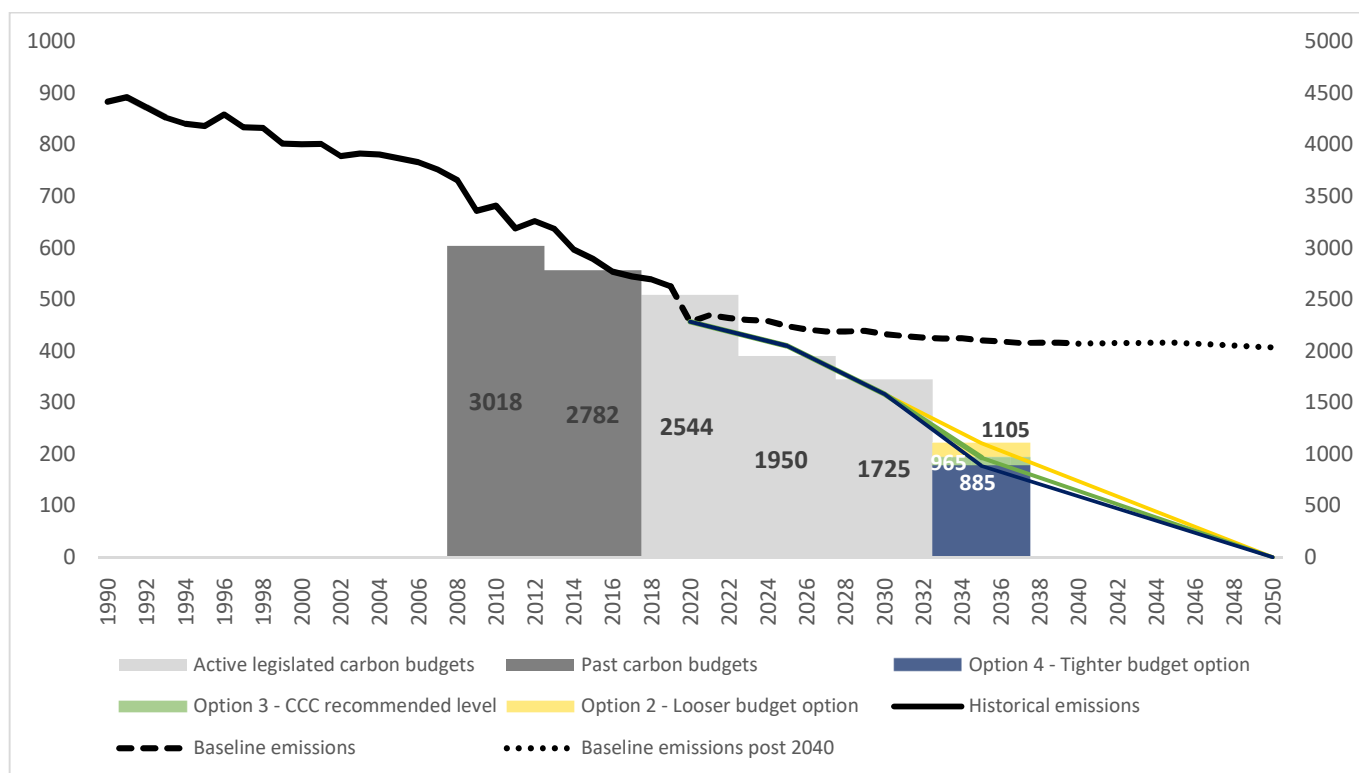
Figure 1: Projected UK territorial emissions including accounting changes compared to published projections of territorial emissions, MtCO₂e



1.7 The sixth carbon budget levels and pathways to 2050

71. To fully assess the options for the sixth carbon budget level it is necessary to consider their implications for the pathway of emissions out to 2050. Given existing targets and commitments, the analysis assumes that all emissions pathways to 2050:
- Meet the fourth carbon budget level (which excludes IAS emissions);
 - Meet the UK’s NDC of an at least 68% reduction in GHG emissions by 2030 compared to 1990 levels (excluding IAS). This is a more ambitious commitment than the fifth carbon budget and hence assumes a higher level of decarbonisation over the period 2028-2032 than when the fifth carbon budget was set;
 - Decline linearly from the end of the sixth carbon budget to reach the legislated target of net zero emissions by 2050 (including IAS emissions).
72. Figure 2 below plots the emissions pathways for the three carbon budget levels compared to the baseline “do nothing” scenario.
73. For the purpose of this analysis, base year (1990) emissions of 887MtCO₂e are assumed. This is on the accounting basis set out in section 1.4. This is an analytical assumption for the purpose of the analysis on the sixth carbon budget, not a projection or prediction of what base year emissions will be.

Figure 2: Modelled sixth carbon budget options in terms of five-year budget level (right axis) and per annum emissions (left axis) against the baseline “do-nothing scenario”, MtCO_{2e}



1.8 Public sector equality duty

74. Under Section 149 of the Equality Act 2010, public authorities have a duty to consider how their policies and decisions affect individuals who are protected under the Equality Act (2010).²¹ The Act 2010 identifies the following as protected characteristics for the duty:

- Age
- Disability
- Gender reassignment
- Marriage and civil partnership
- Pregnancy and maternity
- Race (including ethnicity)
- Religion or belief
- Sex
- Sexual orientation

75. As this Impact Assessment concerns only the decision on the overall level of the sixth carbon budget, rather than the policies needed to meet it, it is not yet possible to identify specific equalities impacts. Where appropriate, the government will consider equalities impacts further as policies and proposals are developed to meet the sixth carbon budget, preceding carbon budgets, and the UK's NDC.

²¹ <https://www.legislation.gov.uk/ukpga/2010/15/section/149>

76. In principle, however, climate change exacerbates inequalities on a global scale and efforts to tackle climate change contribute towards addressing these. The impacts of climate change are not equally distributed across people or communities²² and it is well-established that existing social inequalities result in a disproportionate negative impact among disadvantaged groups.²³ While the impact of mitigation policies is complex, it can both compound and reduce inequalities.²⁴ The IPCC concludes that limiting global warming to 1.5°C would make it significantly easier to achieve many aspects of sustainable development, with greater potential to eradicate poverty and reduce inequalities.²⁵
77. There are also localised inequalities impacts arising from the adverse effects of climate change, although we cannot identify these for the different budget options considered. As an example, health impacts can disproportionately impact different demographics in society, including those with protected characteristics. Research has found the worst levels of air pollution are experienced by those living in the 10% most deprived areas in the UK, regions which have a higher proportion of Black, Asian and minority ethnic (BAME) populations.²⁶
78. Making the transition to net zero in the UK could also impact those with protected characteristics disproportionately, for instance if emerging green jobs were concentrated in sectors that currently have poor diversity, or changing household bills or taxes were to particularly impact specific groups. In transitioning to net zero and bringing forward policies in future, government will need to consider ways to ensure it is representative of people with protected characteristics, while minimising any potential negative impacts.

²² Cameron, Shine and Bevens (2013), *Climate Justice: Equity and Justice informing a new climate agreement*, Working paper, published by MRFCJ and WRI (http://pdf.wri.org/climate_justice_equity_and_justice_informing_a_new_climate_agreement.pdf)

²³ Islam, N. and J. Winkel (2017), *Climate Change and Social Inequality*, UN Department of Economic and Social Affairs (DESA) Working Papers, No. 152, UN, New York (<https://www.un.org/development/desa/publications/working-paper/wp152>)

²⁴ Markkanen, S., & Anger-Kraavi, A. (2019). *Social impacts of climate change mitigation policies and their implications for inequality*, Climate Policy (<https://doi.org/10.1080/14693062.2019.1596873>)

²⁵ Roy, Tschakert, Waisman (2018) 'Sustainable Development, Poverty Eradication and Reducing Inequalities', IPCC

²⁶ UK notification to the European Commission to extend the compliance deadline for meeting PM10 limit values in ambient air to 2011, Racial equality impact assessment (England) (<https://web.archive.org/web/20110710192634if/http://www.endsreport.com/docs/20090820a.pdf>)

2 Analysis

2.1 Evidence base

79. The analysis presented here takes the form of scenarios, not forecasts or predictions. All presented pathways to 2050 are illustrative and created to inform the decision on the level of the sixth carbon budget. They do not define how the sixth carbon budget or net zero will be achieved, which will be for future policy decisions, but they do allow an assessment of the key costs, benefits, risks, and opportunities of different budget levels.

The UK TIMES model

80. The emission pathways modelling, and the majority of monetised cost and benefits, use the UK TIMES model (UKTM)²⁷, a least-cost optimisation model for the whole UK emissions (including land use) and energy system covering the period 2010 to 2060. More details on the UKTM model can be found in annex A.2 but the key points to note are:

- **Methodology:** model inputs include assumptions about technology costs²⁸, availability, performance, and build rates, fossil fuel prices and energy services demand by end-use sector. These inputs are pre-determined for each model run and do not vary with deployment (e.g. endogenous technology learning is not captured beyond pre-determined assumptions). Based on the input assumptions the model identifies the least-cost way of meeting a given GHG reduction trajectory while also meeting assumed end-use demand for energy services.
- **Assumptions:** an extensive exercise has been undertaken to ensure UKTM is aligned with the latest evidence base and assumptions used across government. More detail on assumptions is included in Annex A.2.
- **Strengths and limitations:** a particular advantage of UKTM is that it identifies the least-cost technology pathway for a given set of assumptions, taking account of interactions across energy supply and end-use sectors over time. The model is therefore useful for identifying which technologies could be essential, or important in the long run for achieving a low cost, low carbon system and the appropriate sequencing of abatement opportunities. However, there are a number of limitations to the modelling:
 - a. The model does not directly take account of opportunities or risks to costs and meeting future targets resulting from uncertainty around technological, economic, social, institutional, and environmental factors, or potential benefits and upside risks from technology deployment reducing costs (e.g. learning by doing), including from global action. To assess the uncertainty around these factors various technology scenarios and sensitivities have been analysed, see further detail in section 2.2.
 - b. Not all costs and benefits are accounted for in the model. In particular, there are likely to be additional barriers beside cost and technical build rates that could constrain the realisation of options that UKTM analysis suggests may be important in 2035 or 2050. These barriers are considered separately in section 2.3. Potential industrial benefits and risks (e.g. market opportunities

²⁷ The UK TIMES model has been developed by BEIS and UCL. It is based on the [TIMES model generator](#).

²⁸ The model takes account of the direct cost of purchasing, installing, running and maintaining the abatement technologies. The cost of purchasing and installing includes assumed capital costs and the cost of borrowing to pay for the capital. Running costs include the cost of energy supplies, both domestic and any imports.

from developing and deploying low-carbon technologies or transition risks) are not captured in the model and are therefore considered separately.

- c. The model varies in detail by sector. In some areas only high-level representations are provided and it is not spatially disaggregated.

Supplementary sectoral evidence

81. To complement the UKTM whole-system analysis on technical feasibility, a comprehensive sector specific evidence base has been used to inform the assessment. This includes evidence on:
 - costs and benefits from sectoral modelling frameworks (which provide more granular modelling than UKTM);
 - wider impacts, including international circumstances and sustainability risks;
 - power sector decarbonisation pathways and implications for electricity price impacts.
82. Further information on this supplementary evidence is in Annex A.4.

2.2 Technical feasibility of sixth carbon budget levels

Pathways modelled

83. The technology mix and costs modelled by UKTM are highly sensitive to the availability of key resources (for example biomass) and technology assumptions. Given the uncertainty around these assumptions, for the purposes of this Impact Assessment, four net zero pathways have been developed representing different technology availability and resource conditions. Each sixth carbon budget option, presented in section 1.7, is tested against a range of alternative futures for key technologies and resources:
 - A) Core** pathway – based on the core “central” assumptions as described in Annex A.2.
 - B) High CCS** pathway – to reflect upside technology uncertainty this assumes a 4 percentage point increase in carbon capture and storage (CCS) capture rates for nth of a kind technology (from 95% to 99% in most cases) and higher availability of direct air carbon capture and storage (DACCS) at 25MtCO₂ by 2050 compared with 13MtCO₂ in the other pathways.
 - C) CCS delay** pathway – to reflect downside technology uncertainty this assumes a delay to CCS availability by 5 years (start date changed from 2025 to 2030) and a 5 percentage point decrease in capture rates. This is also the only scenario in which hydrogen imports are allowed (limited to 70TWh) to offset domestic delay in production at scale.
 - D) High resource** pathway – to reflect an alternative plausible resource scenario this assumes an increase in afforestation planting rates²⁹ from 30 kilo-hectares per year (kha/yr) to 50 kha/yr from 2030, and a primarily hydrogen-based decarbonisation route for heating in buildings.
84. These pathways do not represent the full range of technological and sectoral uncertainty associated with the transition to 2050. They have been prioritised based on their whole-system impact and impact on the sixth carbon budget decision.

²⁹ This refers to traditional afforestation, biomass planting rates are the same across all pathways.

85. There are likely to be additional assumptions that strongly influence the UKTM technology mix that have not been assessed here, for example the emergence of currently unknown technologies or shifts in behaviour. Whilst one-off behavioural change (e.g. adoption of new technologies) is implicit in all pathways, shifts in consumption patterns other than those already included in the trend forecasts are not modelled (e.g. diet change, lower or higher heat, aviation or road travel demand).

2050 emissions and energy system

86. The sixth carbon budget needs to be set at a level consistent with achieving net zero emissions by 2050. This section therefore explores what the 2050 end point could look like and how sensitive it is to the sixth carbon budget level.
87. Table 5 summarises the illustrative range of emissions remaining in 2050 by sector under the four pathways considered in UKTM. The emissions picture in 2050 is fairly stable despite the range of uncertainties tested due to the relatively limited solution space to get to net zero. In all pathways the near full decarbonisation of all end-use sectors and deployment of negative emissions technologies at scale will be required by 2050 based on assumptions about the future performance and availability of key technologies.
88. When tested, the 2050 least-cost technology mix is not sensitive to the relatively narrow bound of sixth carbon budget options (Options 2-4) considered in this Impact Assessment. Tighter budget levels do not lock-in higher cost solutions, while looser budgets do not restrict achievement of the 2050 least-cost mix. The impact of varying the budget is mainly to shift the distribution over time of decarbonisation effort and costs between the sixth carbon budget and subsequent budgets. For this reason, all subsequent figures, unless otherwise stated, are consistent with Option 3. The costs and benefits of alternative sixth carbon budget options are assessed in detail in section 2.5.

Table 5: Illustrative total territorial GHG emissions (MtCO_{2e}) under the different technology scenarios³⁰

	2019 emissions (MtCO_{2e})	2050 illustrative emissions range based on modelled pathways (MtCO_{2e})³¹
Domestic transport	122	2 to 5
Industry	66	8 to 9
Fuel supply	38	0 to 5
Buildings	88	0
Electricity	54	~1
Agriculture	55	34 to 35
Waste	29	10
F-gases	15	3
LULUCF³²	8 (13)	-10 to -16
Engineered removals	-	-81 to -91
Int'l Aviation & Shipping	45	33
Total emissions	520 (525)	0

³⁰ Analysis of UK 1990-2019 GHG Inventory, with adjustments to reflect assumptions on the CB6 accounting basis as described in section 1.4 'accounting and scope'. Sectoral definitions broadly aligned with the taxonomy presented in the CCC's advice on Carbon Budget 6 except for energy from waste emissions, which have predominantly been reported against the electricity sector instead of the waste sector. Where it has not been possible to allocate emissions between sectors (fuel supply/industry) based on the latest GHG Inventory consistently, an allocation has been inferred from CCC advice based on the 1990-2018 GHG Inventory. For information on UKTIMES sector definitions, see Annex A.2.

³¹ These ranges only reflect the uncertainty captured in the modelled pathways. There is additional uncertainty that is not reflected here, including in respect to aviation and shipping and waste.

³² Figures in brackets indicate adjustment for Tier 2 peat emissions in line with the accounting scope of this Impact Assessment.

89. The cost-optimal technology and energy mix is more affected by the uncertainty arising from technology and resource availability than by the choice of the sixth carbon budget level. All pathways at least double current electricity generation by 2050 and rely on substantial hydrogen production and biomass use. However, the final energy mix is highly variable depending on the modelling assumptions. The table below summarises the modelled range of energy use.

Table 6: Modelled sustainable energy carriers in 2050 (in TWh)

	2050 illustrative range based on modelled pathways (in TWh)	Key technologies and resources
Electricity generation	610-800	60-80% variable renewable generation 95-100% low carbon generation A variety of low carbon technologies will be needed
Low carbon hydrogen production³³	250-460	20-45% biomass gasification with CCS 5-75% steam methane reformation with CCS 5-50% electrolysis
Sustainable biomass availability	270-280	50% domestic biocrops planting 30% afforestation

90. **Electrification** of transport, certain industrial processes and some heat for buildings is crucial in all scenarios by 2050. However, the extent of electrification in 2050, and therefore electricity demand, varies depending on the modelling assumptions. The highest level of electrification is seen in the CCS delay pathway because technology delay in CCS limits the scope for hydrogen from CCS-enabled domestic production. As a result, hydrogen from CCS is replaced by greater amounts of electrolysis which has additional electricity requirements even if surplus generation from variable renewables is used. The lowest level of electrification is seen in the high resource pathway due to greater hydrogen use in the buildings sector.
91. Given the pivotal role of electricity in delivering net zero emissions, the modelling suggests a fully decarbonised power system by 2050 (with small amounts of residual emissions reflecting CCS capture rates below 100%). There is inherent uncertainty over what that system will look like. Modelling for the Energy White Paper has shown that there is no single optimal technology mix for 2050 with many capacity mixes being able to meet different carbon emissions levels at relatively low cost. The power sector needed will depend on the level of demand, and the cost and availability of low-carbon technologies, particularly low-cost clean hydrogen.
92. Based on the modelled core pathway, in 2050 the majority of **hydrogen** is used in shipping and industrial processes, with some also used for HGVs, electricity production and to provide heating in buildings. The extent to which hydrogen is used across the economy depends on the availability of technologies used in its production and their relative cost and efficiency, which is subject to considerable uncertainty (e.g. CCS performance, availability of renewable electricity and biomass). In the high resource pathway, widespread use of hydrogen in buildings' heating is modelled, leading to higher levels of hydrogen demand. The high CCS pathway also sees a relative increase in hydrogen use (e.g. for industrial fuel switching) as a result of higher capture rates reducing the emissions intensity of CCUS-enabled hydrogen production.³⁴

³³ Excludes imports.

³⁴ UKTM hydrogen cost assumptions are based on the assumption that a new hydrogen grid is built and costs for decommissioning or repurposing the gas grid are not included. If this is more or less costly than assumed in the modelling, findings from the UKTM modelling presented here could understate or overstate the role for hydrogen in meeting 2050 targets.

93. In the core pathway, hydrogen is supplied through a mix of methane reformation with CCS, biomass gasification with CCS (BECCS) and electrolysis, with a smaller role for waste gasification. In the CCS delay pathway, lower capture rates, delayed CCS availability and high renewable electricity deployment lead to more electrolysis and less methane reformation with CCS, while the converse happens in the high CCS scenario. In the high resource pathway, there is substantially higher demand for hydrogen due to widespread use in heat; the additional demand is mostly met through methane reformation with CCS due to cross-cutting constraints on other resources such as biomass. Across all pathways, the role of BECCS is particularly uncertain as it depends on the availability of biomass and the benefits of using biomass in hydrogen production relative to use in other sectors such as industry and electricity generation.
94. A further area of considerable uncertainty is the availability and use of sustainable **biomass**. Based on modelling assumptions, substantial availability of biomass (consistent with 53kha/yr planting rates in the core pathway) is required by 2050 to enable negative emission technologies (bio-energy with Carbon Capture and Storage or BECCS), though use of biomass on the pathway to 2050 is less certain. Much of this land would be in competition with afforestation and the combined rate of land use change presents a risk to natural capital, as set out in section 2.6. Biomass and biomass products are used in industry, electricity generation, hydrogen production and in heating buildings and also transport (primarily aviation). There are considerable uncertainties around the development and costs of biomass to 2050 (including domestic production and availability of imports). Hence, the model may be over-reliant on biomass to meet emissions constraints.
95. The modelling indicates that there is a potential residual **role for fossil fuels** even in 2050, albeit much reduced. The share of fossil fuel products in final energy consumptions is expected to reduce from around 80% today to less than 20% in 2050 and is only prevalent in the hardest to abate sectors of the economy. Residual oil/petroleum use is primarily in the aviation sector, while natural gas use is limited to CCS enabled technologies (e.g. production of hydrogen and combustion for electricity generation).
96. Table 7 summarises the main abatement technology options identified as likely to be important in the modelled 2050 least-cost technology mixes by sector. As more information becomes available and understanding of possible technologies and consumer preferences develops over time, uncertainty over the cost-effective path and technology mix for net zero will reduce.

Table 7: Illustrative summary of end-use sector technologies and their deployment requirements in 2050 (based on Option 3)

	Key abatement technologies	Current	2050 illustrative range based on modelled pathways (Net Zero)³⁵
Surface transport	Electric cars and vans (millions) Zero Emission HGVs (share of fuel %)	0.2	45-50 91-100
Industry	Carbon capture and use (Mt) Sustainable fuels (% of final energy use)	0 30	6-12 75-85
Buildings	Domestic: low carbon appliance and district heat share of heat supply (%)	10	100
	Non-domestic: low carbon appliance and district heat share of heat supply (%)	14	100
Agriculture	Low-carbon farming practices, metrics not quantifiable	n/a	Metrics not quantifiable
Waste	Cease biodegradable waste to landfill ³⁶ Municipal recycling target		By 2030 65% by 2035
LULUCF	Afforestation (kha/yr)	13.5	30-50
	Bioenergy crops planting (kha/yr)	0	53
	Peat restoration (kha restored)	n/a	380
Carbon Capture, Use, and Storage	Total captured (Mt)	0	100-160
	Direct Air Capture (Mt)	0	13-25
	BECCS (Mt)		65-70
Aviation and shipping	Biofuels for aviation (share of fuel %)	0	5
	Ammonia for shipping (share of fuel %)	0	97

2035 emissions and energy system

97. This section explores what can be deduced about the sixth carbon budget period, including both the level of decarbonisation and the way in which this decarbonisation is undertaken. The aim is to assess the extent to which the sixth carbon budget level options are reliant on uncertain technologies or stretching deployment requirements.
98. The section above highlighted the range of technologies that could be important for 2050 and illustrated how the 2050 target could be met. If the UK were to keep options open to accommodate the different potential outcomes in 2050, then by 2035 the UKTM modelling suggests that for any given level of the sixth carbon budget there should be:
- A significant increase in the electrification of end-use sectors such as transport, heating and industry, and continued decarbonisation of the power grid;
 - Substantially improved energy efficiency in all sectors either via adoption of new more energy efficient technologies or direct investment in energy efficiency measures (e.g. solid wall insulation);
 - Deployment of low carbon hydrogen, CCS and greenhouse gas removal technologies at scale;

³⁵ These ranges only reflect the uncertainty captured in the modelled pathways. There is additional uncertainty that is not reflected here, including in respect to aviation and shipping and waste.

³⁶ i.e. diverting the following municipal waste from landfill: food, paper/card, wood, textiles and garden waste.

- Increased switching to low-carbon fuels (e.g., hydrogen, biomass) in hard to electrify areas of the economy such as industry, heavy transport, aviation and shipping;
- Implementation of available abatement options across all natural resources sectors (e.g. afforestation, low carbon farming practices).

99. The table below summarises the illustrative range of emissions remaining in 2035 by sector under the different sixth carbon budget options considered.

Table 8: Illustrative emission ranges in 2035 under different sixth carbon budget levels, based on the modelled pathways³⁷

Emissions in MtCO ₂ e	Baseline-Do-nothing	Option 2 – Looser	Option 3 – CCC	Option 4 - Tighter
Domestic transport	83	41-49	30-37	21-28
Industry	37	20-21	15-17	15-17
Fuel supply	46	17-20	8-11	8-9
Buildings	98	48-53	44-47	41-47
Electricity	26	7-12	7-12	7-12
Agriculture	48	43	42-43	42
Waste	16	12	12	12
F-gases	5	3	3	3
LULUCF	18	(0-1)*	(0-1)	(0-1)
Engineered Removals	0	(13-19)	(13-19)	(14-22)
IAS	46	40	40	40
Total emissions	420	221	193	177

* Brackets indicate negative values

100. **Tightening the sixth carbon budget progressively** from Option 2 to Option 3 has limited to no effect on land-use, agriculture, and removals emissions as feasible cost-effective abatement is already exhausted at the looser budget level. Electrification increases by around 12% in Option 3 compared to Option 2 under the core pathway, requiring more low carbon generation capacity. Option 3 does not rule out hydrogen for heating as a long-term option, but a hydrogen pathway for buildings would require additional decarbonisation options in buildings (such as heat pumps) or additional effort in other sectors (e.g. land use and transport) to account for widescale hydrogen heating being less available by the mid-2030s than electrification.
101. Sectors pushed further in Option 3, indicating higher marginal cost solutions in these sectors, include surface transport, fuel supply, industry, and buildings. The CCS delay pathway reduces the scope for industrial decarbonisation and engineered removals, requiring more emissions abatement in surface transport indicating that the model finds surface transport is the marginal sector both across budget levels and also technology / resource pathways.
102. The tightest budget level considered, Option 4, involves going even further in the transport, industry, fuel supply and buildings sectors. In particular, the cost-optimal pathways for this sixth carbon budget level imply a large acceleration in the decarbonisation of domestic transport which is likely to be very challenging and costly from a delivery perspective (i.e. the rate of adoption exceeds the natural stock turnover of cars and vans). Furthermore, there is some evidence that the tightest sixth carbon

³⁷ These ranges only reflect the uncertainty captured in the modelled pathways. There is additional uncertainty that is not reflected here, including in respect to aviation and shipping, and power and waste. Specifically, UKTM power sector modelling assumes some abatement from electricity from waste plants that would require a change to current policy.

budget level considered would imply greater use of hydrogen and biomass in the transport and electricity sectors than the model suggests is optimal over the long-term leading to un-economical investments if taken forward.

103. Taken together, the UKTM pathways evidence suggests that all the sixth carbon budget options are technically feasible and are consistent with a range of low-cost pathways to 2050, but the tightest option could lead to non-economical outcomes. The CCC recommended level (Option 3) is consistent with bringing forward electrification in heating and transport, and fuel switching in industry that the model suggests is needed long-term. The model chooses a smoother, slightly less costly, deployment trajectory of the same technology mix under the looser option (Option 2).
104. In terms of the **fuel mix**, more frontloaded decarbonisation results in more rapid electrification and consequently electricity demand in 2035 is higher for the tighter sixth carbon budget options. The role of hydrogen in the sixth carbon budget period in the modelled UKTM scenarios is increasingly important. The main roles for hydrogen in the model during this period are to provide fuel switching in industry, fuel for heavy goods vehicles, ammonia production for shipping, and a potential low-carbon source of flexible electricity generation. In the high resource pathway this is augmented by increased hydrogen demand for heating buildings.
105. More frontloaded decarbonisation increases the burden on the electricity and hydrogen sectors. Detailed power sector modelling suggests that it is feasible to get to the grid intensity implied by the UKTM pathways, however the optimal mix of generating technologies will depend on their relative cost and availability. Without hydrogen generation for peaking demand, most core low-carbon generation technologies would have to deploy near their maximum technical potential. A further key area of uncertainty is energy from waste, which by 2035 is expected to make up a large share of power sector residual emissions. The availability of hydrogen generation can reduce the burden on other technologies, but the technical challenge remains significant. In all the pathways, apart from CCS delay, hydrogen supply in 2035 is predominantly from methane reformation with CCS, as BECCS technology is not assumed to deploy at scale until the mid-2030s, and electrolysis will not have scaled up by that time due to the cost of electrolyzers and availability of renewables. This indicates that blue hydrogen is needed to provide scale in the short to medium term, before lower emissions technologies become available and cost-competitive at scale.
106. Across the sixth carbon budget options it is generally more cost-effective to deploy biomass in industry, hydrogen production and electricity generation than to use it for heating buildings and transport. Balancing supply with demand considerations and avoiding sustainability issues will be an important consideration in policy development in this area. Under all carbon budget levels, the UKTM modelled least-cost technology mix includes more biofuels in aviation in 2035 than in 2050. This is only one illustrative view of the emissions pathway for aviation. For example, synthetic fuels, not modelled due to lack of robust data on the implications for the energy system, could be an alternative fuel source in the transition if they prove to be cost-effective.

Table 9: Modelled sustainable energy carriers in 2035 by option (in TWh)

2035 TWh	Baseline Option 1 - Do-nothing	Option 2 - Looser	Option 3 - CCC	Option 4 - Tighter
Electricity generation	300	415-485	465-515	500-540
Variable renewable generation (%) ³⁸	50	65-75	65-75	65-75
Low carbon generation (%)	80	95-99	95-99	95-99
Low carbon hydrogen production³⁹	0	70-115	85-125	110-140
Biomass gasification with CCS (%)		5-10	5	5-10
Steam methane reformation with CCS (%)		20-90	50-85	50-75
Electrolysis (%)		0-45	5-40	15-40
Sustainable biomass use	100	210-270	265-310	305-350

107. Table 10 summarises the **key abatement technologies** and their deployment requirements based on the modelled illustrative core pathway. Where possible UKTM modelled deployment metrics have been supplemented with technical abatement potential from more detailed bottom-up sectoral modelling.

Table 10: Illustrative summary of key technologies and their deployment requirements in 2035 based on the modelled pathways⁴⁰

	Key abatement technologies	Option 2 - Looser	Option 3 - CCC	Option 4 - Tighter
Carbon Capture, Use, and Storage	Total captured (Mt)	20-45	25-45	25-50
End-use sector				
Surface transport	Electric cars and vans (total, million)	15-24	24-27	25-30
	Zero Emission HGVs (share of fuel %)	25	35-50	70-80
Industry	CCUS (Mt)	3-4	3-6	2-7
	Sustainable fuel use (% share of final energy use)	60-65	65-70	70
Buildings	Domestic: low carbon appliance and district heat share of heat supply (%)	35-40	40	40-45
	Non-domestic: low carbon appliance and district heat share of heat supply (%)	70-80	80	80
	Total heat conserved (TWh)	80	80	80
Agriculture	Low-carbon farming practices	Metrics not quantifiable		
Waste	Cease biodegradable waste to landfill ⁴¹	By 2030		
	Municipal recycling target	65% by 2035		
LULUCF	Afforestation (kha/yr, Mha)	30-50, 0.5-0.7		
	Bioenergy crops planting (kha/yr, Mha)	53, 0.7		
	Peat restoration (kha restored)	250		
Removals	BECCS (Mt)	13-19	13-19	14-22

³⁸ Variable renewable and low carbon generation metrics relate to the expected percentage of domestic generation.

³⁹ Excludes imports.

⁴⁰ These ranges only reflect the uncertainty captured in the modelled pathways. There is additional uncertainty that is not reflected here, including in respect to aviation and shipping and waste.

⁴¹ i.e. diverting the following municipal waste from landfill: food, paper/card, wood, textiles and garden waste.

Aviation & shipping	Biofuels for aviation (%) Ammonia for shipping (%)	7-8 29-32	7-8 29-32	7-8 31-32
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Sensitivities

108. To establish the implications of higher/lower than expected **economic growth** on the core pathways, UKTM has also been run with two additional economic growth scenarios that model a +/-0.25 percentage point per year uncertainty range around the OBR's July 2020 short-term upside and downside scenarios and the March 2020 long-term forecasts. The overall sensitivity implies a +10% or -9% increase or decrease in the level of GDP by 2035. These scenarios include no structural changes in the UK economy, but it should be acknowledged that structural changes could also affect UK emissions, particularly in sectors subject to high levels of global competition, e.g. industry.
109. Generally, higher economic growth scenarios lead to higher decarbonisation costs, due to the additional infrastructure needed to meet higher energy demands over the transition and some more expensive technologies in the long run. There is a significant impact on supply side sectors due to the need to meet higher levels of demand and fuel switching (e.g. demand for clean electricity in 2050 is 20% higher in 2050). The reverse applies to lower growth scenarios.
110. To test the implications of higher and lower **fossil fuel prices** the core pathways were also run with BEIS's 2019 high and low fossil fuel price assumptions.⁴² Lower fossil fuel prices lead to higher overall energy demand and moderately higher decarbonisation costs, because the value of fossil fuel use savings are reduced. Conversely, higher fossil fuel prices lead to lower demand and decarbonisation costs because the resource savings from switching away from fossil fuels are higher. The impact on the share of emissions across end-use sectors and the technology mix is more variable than under central fossil fuel prices for all carbon budget levels. This highlights the importance of fossil fuel price assumptions for the consideration of the cost-effective pathway (e.g. transport emissions under low fossil fuel prices are higher due to a reduction in the cost-effectiveness of fuel switching and higher underlying transport demand).
111. The costs and benefits of these modelled scenarios are assessed further in section 2.5.

Summary: Technical Feasibility

112. In summary, the UKTM pathways evidence suggests that all the sixth carbon budget options are technically feasible, and Options 2-4 are consistent with a range of least-cost outcomes in 2050. All options apart from the do-nothing option (Option 1) meet the net zero target. Analysis suggests that tighter budget levels are more stretching across all sectors and that Option 4 (the tightest option) could lead to non-economical outcomes.

2.3 Delivery Implications

113. The UKTM model addresses the technical feasibility of reaching the sixth carbon budget levels but does not consider non-technical barriers to policy delivery. This Impact Assessment is policy agnostic and therefore does not analyse barriers to specific policies that may be required to deliver the carbon budgets. Instead, this section presents a qualitative and illustrative discussion of some of the expected barriers in each sector.

⁴² BEIS 2019 Fossil fuel price assumptions. <https://www.gov.uk/government/publications/fossil-fuel-price-assumptions-2019>

114. This section mainly considers the delivery implications of the sixth carbon budget, but it is also the case that the level of the sixth carbon budget will influence the deliverability of the 2050 net zero target. Whilst all the modelled budget options apart from the do-nothing option meet net zero, successful delivery of a tighter sixth carbon budget level would help de-risk the net zero target compared to a looser option.
115. Since the policies required to meet the sixth carbon budget levels are as yet undecided, it is not possible to analyse the difference in the level of barriers of the sixth carbon budget levels considered in this Impact Assessment. However, it is expected that the marginal policies used to meet tighter sixth carbon budget levels will be more challenging.
116. Across the considered sixth carbon budget levels, except the do-nothing option, all sectors will need to pursue policies that have some barriers to delivery. Consumers and producers will have to change the technologies they interact with and use, and in many cases the up-front costs of low carbon technologies, such as heat pumps, are currently higher than the technologies they replace. Supply chains for low carbon technologies will need to be significantly scaled up and, in some cases, key technologies will need to be demonstrated ahead of their wider-scale deployment. In almost all cases, widespread government intervention will be needed to overcome these barriers.
117. The barriers considered here are:
- **Technical barriers**, including scaling-up existing technologies and maturing and developing new technologies.
 - **Market barriers**, including the development of fit-for-purpose infrastructures and supply-chains.
 - **Behavioural barriers**, including the necessary adoption of sustainable behaviours by consumers and businesses, including shifts towards purchasing and using new technologies.
 - **Socio-political barriers**, including impacts on local communities and legislative requirements.
118. In the **agricultural sector**, there are significant behavioural barriers. Most technical abatement options (such as installation of drainage systems, integrating grass and herbal leys, slurry covers) involve significant upfront costs, while installing and using the technologies is potentially disruptive for farmers. However, the main technologies do not require significant development, and supply chain issues are not expected. Where policy options involve land management change, there will be trade-offs and competition with other competing demands on land use.
119. In the **buildings sector** there are significant barriers of all types. Emissions abatement requires a significant proportion of homeowners, tenants, landlords, businesses and the public sector to install and use low-carbon heating systems as they replace existing fossil fuel heating systems. Higher building fabric costs, disruption and awareness are all issues. Though most of the technology options are known, supply chains for key technologies, such as heat pumps, will need to be significantly ramped up to meet needs. Workforce constraints will be an issue without intervention. A hydrogen scenario for buildings decarbonisation would present different and significant barriers; research and development is required to guarantee safety and feasibility, and large scale infrastructure build and new regulation would be needed to create new markets at the necessary scale.
120. In the **power sector**, high levels of government intervention and legislation will be required. The supply chains and skilled workforces to support them will need to be

significantly scaled up on existing levels, which will require government incentives. Most of the required technology is mature, but there are some areas, such as energy storage, hydrogen generation and flexibility technology, that need development and innovation. Frontloading electrification and a higher level of ambition in the power sector increases the burden on the power sector. This level of ambition will impact costs; faster progress now may put us onto a pathway to a more expensive electricity system in 2050, due to the mix of technologies that it is possible to deploy quickly. The sixth carbon budget will also impact the level of low carbon build, with increases likely to be required across all key low carbon technologies. This will create a significant delivery risk. The increased ambition required under the sixth carbon budget must also be achieved whilst maintaining high levels of security of supply, given that electricity is a necessity in a modern industrial economy and key to decarbonising other sectors. Such a high build rate of low carbon technologies could create capacity adequacy and system operability issues that will need to be overcome.

121. In the **land use sector**, there are significant barriers of all types. Afforestation and peatland restoration will require significant behaviour and culture changes by farmers and landowners, for which there is little financial incentive without government intervention. The need to take peatland out of agricultural production may face public opposition. Most necessary technology is mature, but lowland peat restoration will require innovation. Availability of scarce land is a significant barrier to afforestation and peat restoration, given competing land needs. Infrastructure and workforces for peat restoration will need to be scaled up. Overall, the delivery risk in the land use sector should not be underestimated given that the likely needed planting rates for afforestation and biomass for all sixth carbon budget levels are nearly an order of magnitude greater than current rates and, in the main, require incentives/regulations to facilitate planting on private land (i.e. land that government is not in control of). Furthermore, such an acceleration is likely to require significant trade-offs with water availability, landscape and biodiversity. For afforestation, the abatement profile and maximum level is dependent on the nature of the woodland planted and method of establishment; as a consequence, there are likely to be trade-offs between carbon abatement and nature recovery commitments made in the 25 Year Plan for the Environment.
122. In the **waste sector**, there are some barriers, particularly relating to changes in behaviour. Engagement and adoption of new behaviours will be required from producers, local authorities and consumers as packaging is improved and reduced and waste collection is improved by ensuring a consistent set of dry recyclable materials is collected from all households and businesses and offering weekly food waste collections. Additional market capacity may be needed, and some government intervention is likely required.
123. In the **transport sector**, there are major barriers of all types. Encouraging take up of electric vehicles is a major challenge, with particular difficulties around current higher vehicle costs, and charging practice and times. Most car and van technologies are mature, whilst many alternative technologies for HGVs, hydrogen trains, advanced biofuels, sustainable aviation fuels and low-carbon shipping are in development or need to be demonstrated before they can be deployed at scale. Significant cost reductions and / or government intervention will be required to enable widespread deployment of these technologies, and achieve any necessary behaviour change by businesses and consumers. Production will need to scale up very significantly, especially for charging infrastructure, alternative fuel infrastructure and batteries, with the latter depending on scarce resources. For biofuel solutions, competition for land use and biomass feedstocks could be challenging. Regulatory measures are expected to be needed.

124. In the **industry sector**, there are significant barriers, particularly because many technologies are not yet commercially viable, have high up-front costs or have yet to be demonstrated at scale. Consumers and producers will need to shift towards lower carbon intensity, for which carbon pricing or other financial incentives will be needed. Markets need to be scaled up and workforce upskilling or retraining may be required. Where fuel switching to hydrogen is expected, significant infrastructure and supply chain development will be necessary for widespread take-up.
125. **Carbon capture** faces a variety of barriers, most notably the innovation and deployment support needed to bring carbon capture technology to maturity, particularly DACCS. Land use trade-offs and limited biomass availability may be a barrier to scale up of BECCS and, for land use, DACCS. CO₂ transport and storage networks and infrastructure will need to be developed to scale all carbon capture technologies.
126. There are also significant barriers to **hydrogen supply**, distribution, storage and use. Low carbon hydrogen production and end-use technologies have not been demonstrated at scale in a commercial setting, and hydrogen is more expensive than existing fossil fuel technologies in most end-use sectors. Widespread use of hydrogen will require hydrogen distribution and storage infrastructure to be built, and CCUS-enabled hydrogen production will also depend on the development of CO₂ transport and storage networks. A new regulated market for hydrogen will also need to be established. Uptake of hydrogen would require sustainable behaviour adoption across end-use sectors, where users will have to change from fossil fuel to hydrogen appliances.

Summary: Delivery implications

127. In summary, despite the analysis not considering or committing to the specific policy requirements for the sixth carbon budget, it shows that all options considered (except the do-nothing option) will require overcoming significant challenges across all sectors. Whilst the relative difference between the different budget options cannot be known in the absence of specific policies, it is likely that tighter budget levels face more challenges.

2.4 International circumstances

International commitments on climate change mitigation

128. At an international level, the UK is a signatory of both the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement, which in 2015 affirmed the global ambition to limit global temperature rises to 'well below 2°C' and to pursue efforts to limit the temperature increase to 1.5°C. The Paris Agreement has been ratified by 191 countries as of February 2021, accounting for more than 90% of global emissions.
129. As part of the UNFCCC process, the UK successfully bid, in partnership with Italy, to assume the presidency of the 26th annual session of the Conference of Parties to the Convention, or "COP26", to be held in Glasgow in November 2021. The summit aims to accelerate global action towards the transition to a zero-carbon economy through international cooperation and the agreement of a balanced negotiated package for the implementation of the Paris Agreement. From a climate change mitigation ambition perspective, COP26 aims to encourage countries to come forward with commitments to further emission cuts by 2030, in line with a long-term pathway towards reaching net zero emissions as soon as possible.

The UK's emissions reduction commitments at an international level

130. The UK was previously included in the EU's joint intended NDC under the Paris Agreement. In December 2020 the UK submitted its own economy wide NDC which commits to reducing GHG emissions by at least 68% (excluding IAS emissions) by 2030 on 1990 levels. The level of the NDC is consistent with advice from the CCC and the UK's commitment to reach net zero emissions by 2050. The CCC has stated that an NDC of at least 68% 'would constitute a decisive commitment to a net zero emissions trajectory, consistent with the Paris Agreement', which 'would place the UK among the leading countries in climate ambition.' In line with common NDC practice, the UK's NDC target does not include international aviation and shipping. All options under consideration in this assessment assume this target is met, except for the counterfactual scenario.
131. Ahead of COP26, the UK will publish a comprehensive Net Zero Strategy, setting out the government's vision for transitioning to a net zero economy by 2050, making the most of new growth and employment opportunities across the UK. The Net Zero Strategy will constitute the UK's revised Long-Term Low Emission Development Strategy to the UNFCCC.

Global action on climate change

132. Global warming is driven by the increase in atmospheric concentrations of GHGs, determined by cumulative global net GHG emissions. There is no single level of emissions or emission pathway that is compatible with a given degree of warming. A range of emission pathways will be compatible with a given degree of warming depending on assumptions regarding when global emissions peak, their speed of decline after the peak and availability of negative emissions technologies.
133. The IPCC Special Report on 1.5 degrees of Global Warming (IPCC SR1.5) includes an analysis of global mitigation pathways compatible with the Paris temperature goal.⁴³ The report highlights that all Paris-compatible global trajectories have a common pattern: an early emissions peak, followed by rapid and deep emission reductions leading to global net zero emissions in the future.
134. All other factors being equal, global emissions pathways associated with lower global temperature rises tend to imply faster emissions reductions and earlier timings of global net zero. That is, 1.5°C pathways generally require faster and deeper action than well below 2°C pathways. For instance, the IPCC SR1.5 concludes that in model pathways that limit global warming to 1.5°C with no or limited overshoot, global CO₂ emissions decline by about 45% from 2010 levels by 2030 (40-60% interquartile range), reaching global net zero around 2050 (2045-2055 interquartile range); in pathways that limit global warming to well below 2°C, global CO₂ emissions decline by about 25% from 2010 levels by 2030 (10-30% interquartile range) and reach global net zero around 2070 (2065-2080 interquartile range). It is also worth noting that the assessment models used to derive these pathways tend to be global cost-optimisation models, suggesting that early action (or frontloaded) pathways tend to be more cost-effective at a global level than delayed action (or backloaded pathways).

⁴³ IPCC, 2018: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

Table 11: Paris-compatible emissions pathways⁴⁴

Kyoto GHG (AR4) GtCO ₂ e	Global Annual Emissions (interquartile range in brackets)				Timing of Global Net Zero
	2019	2030	2050	2100	Year
1.5 Degrees Low or No Overshoot	59.1 (+/- 5.9)	27.4 (30.9, 24.7)	6.5 (9.6, 4.2)	-3.7 (-1.8, -7.8)	2067 (2061, 2084)
Well Below 2 Degrees		39.6 (45.1, 35.7)	18.3 (20.4, 15.2)	2.1 (4.2, -2.4)	Post-2100 (2090, >2100)

135. Current international commitments under the Paris Agreement (i.e. aggregate Nationally Determined Contributions) do not put the world on track to meet the Paris temperature goals. According to the UNEP Emissions Gap Report 2020, current aggregate NDCs as of November 2020 would lead to a temperature increase of at least 3°C by the end of the century, signalling the need for a significant step-up in climate change mitigation ambition if the Paris temperature goal is to remain within reach. The report estimates a global emissions gap in 2030 of 12-29GtCO₂e between the more ambitious end of current aggregate NDCs and Paris-compatible emissions scenarios. The UNFCCC’s Interim NDC Synthesis Report found limited progress on NDC ambition from updated NDCs submitted up to the end of 2020.
136. However, recent long-term net zero announcements from some of the major economies provide grounds for some optimism, building momentum towards COP26. The impacts of the announcements on global temperatures will crucially depend on the speed and certainty of policy action, with significant associated uncertainties. More information is included in the ‘Commitments of other countries’ section below.

UK contribution towards Paris temperature goal

137. Climate change is a global inter-generational negative externality that requires coordinated, decisive and long-lasting action from all countries. It is therefore reasonable to assess what an appropriate contribution should be for the UK to make towards overall global emissions reductions.
138. The Paris Agreement is not prescriptive about what an appropriate contribution towards the global temperature goal should look like for each signatory; however, it explicitly references the principles of equity and common-but-differentiated responsibilities and respective capabilities as guiding principles for the Agreement’s implementation.
139. There is no single internationally accepted standard methodology for measuring or assessing whether a country’s emissions reduction target represents an appropriate contribution towards the Paris temperature goal. This Impact Assessment therefore investigates a range of potential interpretations by considering the following dimensions:
- Comparison to global averages consistent with Paris-compatible pathways
 - Top-down global effort sharing approaches which take into consideration: (i) cost-effectiveness of global action, (ii) countries’ forward-looking convergence to

⁴⁴ 2019 emissions figures from UNEP Gap Report 2020. All other emission figures from IPCC Special Report on 1.5 degrees of Global Warming.

similar emissions performance metrics and (iii) countries' historical emissions responsibilities.

Global average pathway comparisons

140. This section compares emissions implied by the different sixth carbon budget options with the average reductions required by the world as a whole to meet the Paris temperature goal. This is one of the approaches that was used by the CCC as the basis for their recommendation of a 2050 UK net zero target, which was adopted by Parliament in 2019. The approach was also complemented and expanded in the CCC's advice on the sixth carbon budget level and UK NDC. The CCC suggests that the recommended budget level is "broadly aligned to global pathways for the Paris Agreement, including the 1.5°C goal" and that "any slower reductions to 2035 would bring into question whether the UK could be credibly considered to be pursuing efforts to limit warming to 1.5°C".
141. The table below compares the UK emission reductions implied by the different sixth carbon budget options under consideration with estimates of the emissions reductions to be delivered by the world as a whole in scenarios that achieve the Paris Agreement temperature goals. The table focuses on emissions per capita as an illustrative metric.

Table 12: Comparison to global averages (emissions per capita)⁴⁵

Global scenarios and the sixth carbon budget options	Emissions per capita in 2035, tCO₂e/capita/year	Cumulative CO₂ emissions per capita (2020-2050), tCO₂/capita
Well Below Two Degrees: Global Average	3.8 (2.8, 4.6)	84 (62,105)
1.5 Degrees with No or Low Overshoot: Global Average	2.4 (1.6, 2.9)	53 (33, 67)
Option 1: Do Nothing (non-binding sixth carbon budget)	6.0	152
Option 2: Looser budget option	3.2	71
Option 3: CCC recommendation	2.8	67
Option 4: Tighter budget option	2.6	65

142. Apart from 'do nothing', all options deliver emission reductions on a per capita basis that, if followed globally, would be consistent with the global ambition to keep the increase in global average temperature in line with the Paris Agreement temperature goal. Relative to Option 2, Options 3 and 4 would fare more favourably from a global climate leadership perspective by delivering faster emission reductions, resulting in lower cumulative emissions to 2050 and in emissions per capita levels in 2035 that are marginally closer to the upper end of the 1.5°C ambition. Although there is uncertainty, the different trajectories lead to different outcomes, and looser pathways, all else being equal, will lead to higher global temperature, higher risks of extreme events or require a risky greater reliance on GHG removal technologies in the long-term to meet the Paris Agreement's temperature goal.

Effort-sharing approaches

143. This section includes an assessment of what UK action could be considered cost-effective, fair and equitable under different global warming scenarios and interpretations

⁴⁵ Median values presented with uncertainty range (10th-90th percentile) in brackets.

of how to allocate effort shares in global emissions reductions. A cost-effective allocation scenario assumes that global emission abatement costs are minimised at any point in time given a global emissions target and derives what could be considered an economically efficient UK share of global emissions reduction efforts. Equity-based allocations instead consider other factors, such as differing levels of economic development and historical emissions between countries.

144. Effort-sharing approaches can be used to frame domestic emission reduction levels in the context of global climate action but should not be interpreted as providing a firm indication of what that level should be. There is no internationally agreed methodology to derive a country's equitable or fair contribution towards mitigating climate change. The results of equity-based allocations will depend on value judgements about the relevant importance of different fairness principles. Similarly, a purely cost-effective effort allocation does not differentiate between countries' national circumstances.
145. Moreover, effort-share approaches narrowly focus on different ways of allocating a global mitigation burden amongst countries and fail to capture other important wider economic and equity considerations. For instance, they do not capture the extent of potential damages of climate change impacts, which are likely to vary significantly across countries. They also fail to capture any potential wider economic opportunities and benefits from net zero transitions, including the potential for development of low-carbon jobs, technological innovations and relative competitive advantages or co-benefits to health from mitigation.
146. Effort-share analysis considers only domestic abatement. When framing domestic action in the context of global climate change mitigation efforts, it is also important to note that the potential for the development of global carbon markets under the Paris Agreement cooperation frameworks and the provision of international climate finance provide further instruments for coordinating global action beyond domestic emission reduction targets. In addition to domestic emission reduction commitments, the UK is also currently supporting low carbon growth in developing countries. The UK's International Climate Finance (ICF) helps developing countries mitigate and adapt to the impacts of climate change, reduce deforestation and pursue clean economic growth. At the United Nations Climate Action Summit, the Prime Minister committed to double the UK's ICF to at least £11.6bn between 2021 and 2025. This represents a doubling of the UK's commitment to spend at least £5.8 billion on tackling climate change from 2016 to 2020.

Economically efficient share of global mitigation efforts

147. This scenario considers the combination of countries' abatement targets that would lead to equal marginal costs of abatement across countries. The BEIS Global Carbon Finance (GLOCAF) model has been used to assess the economically efficient allocation level. More details on the GLOCAF model can be found in Annex A.3.
148. This approach allocates mitigation efforts in a way that minimises the aggregate global costs of achieving a global emissions abatement target. It does not differentiate between different sources of abatement and only considers technical feasible abatement potential and costs as guiding principles for the distribution of mitigation efforts. Results are reported in table 13.

Equity-based contributions to global mitigation efforts

149. The relevant academic literature has considered a wide range of potential different metrics to allocate global mitigation efforts under different interpretations of fairness.⁴⁶ These approaches tend to consider allocation methodologies based on historical emission levels or forward-looking convergence to similar emissions performance metrics based on emissions per capita, national income or ability to pay. This Impact Assessment considers the following metrics:

- ‘Capability’ and ‘Contraction and Convergence’, which allocate emissions on the basis of relative GDP per capita or emissions per capita.
- ‘Equal Cost’, which assumes mitigation efforts are shared such that abatement costs as a share of GDP are equal across countries; this is equivalent to a flat tax rate on income.
- ‘Global Carbon Budget’ and ‘Weighted Global Carbon Budget’, which allocate mitigation efforts on the basis of historical emissions.

150. The table below reports the results of the effort-share analysis under a global well below 2°C trajectory and a global 1.5°C trajectory. Detailed descriptions of the fair share methodologies applied are in the Annex. Due to data limitations, it was not possible to include international aviation and shipping emissions in the effort-share analysis results.

Table 13: Illustrative 2035 UK contributions to global emissions reductions

UK effort-share, % reduction on 1990 in 2035 (exc. IAS)	Minimum global cost	Equal Cost	Contraction and Convergence	Capability	Global Carbon Budget	Weighted Global Carbon Budget
Well Below 2°C	63%	74%	68%	91%	99%	87%
1.5°C with no or low overshoot	76%	86%	80%	94%	106%	96%

151. The percentage reductions for the sixth carbon budget options presented above (e.g. table 4) cannot be compared to the percentage reductions in table 13, as they are based on different accounting assumptions. For example, when put on a comparable basis, Option 3 for the sixth carbon budget level implies a reduction of c. 84% on 1990 levels on the same accounting basis as table 13. After adjusting for those accounting differences, in 2035, modelled sixth carbon budget options imply emission reductions that are more ambitious than if global mitigation efforts were shared across countries/regions in the most cost-effective way. They are less ambitious than if efforts were shared with historical contributions to emissions taken into account. They are within the range of reductions implied by effort allocations based on forward looking convergence on common emissions performance metrics.

152. It is worth noting that the analysis implicitly assumes that the global emissions abatement target will be met under each effort-sharing approach only if all countries adhere to the same effort-sharing allocation. Also, the metrics do not necessarily imply emission reductions that are consistent with the UK’s long-term net zero target. These equity approaches therefore provide a guide for what an appropriate contribution from the UK would be to the global emission reduction, not all of which should necessarily be delivered through domestic emissions cuts.

⁴⁶ A review and summary of results of different effort shares approaches is presented in the IPCC Working Group III Fifth Assessment Report. IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Commitments of other countries

153. Since the UK became the first major economy to pass a net zero emissions target into law, countries representing about 70% of world GDP (2018) and approximately 65% of global GHG emissions (2016) have come forward with, or are discussing, net zero or climate neutrality commitments. These commitments propose a range of dates for the achievement of net zero.
154. Alongside these commitments, countries have been encouraged to come forward with more ambitious NDCs ahead of COP26, as required by the Paris Agreement. Whilst NDCs required ahead of COP26 propose emissions reduction targets for 2030 and so are not directly comparable to the years covered by the sixth carbon budget, they present a benchmark for international comparison of climate ambition and commitments. Countries will be required to bring forward commitments covering the period after 2030 by 2025. Despite NDCs becoming increasingly transparent, it is difficult to directly compare targets between different countries due to national circumstances. Uncertainties remain over the sectors and gases that targets cover as well as differences in the accounting rules for LULUCF emissions. Countries can also report NDCs using different metrics and base-years. The table below summarises the emissions reduction targets adopted by the G20 countries.

Table 14: Summary of climate targets of G20 countries

Country	2030 GHG target *	Net zero target ⁴⁷
UK	At least 68% reduction on 1990	Net zero GHG emissions by 2050
Argentina	Absolute emissions target of 359 MtCO _{2e}	Carbon neutral by 2050, committed in NDC
Australia	26-28% reduction on 2005	Under discussion
Brazil	37% reduction on 2005 by 2025, with 2030 target of 43% reduction	Carbon neutral by 2060, committed in NDC
Canada	30% reduction on 2005 by 2030	Net zero GHG by 2050, proposed legislation
China	60-65% reduction in emission intensity of GDP compared to 2005	Carbon neutral before 2060, in policy document
European Union	At least 55% reduction on 1990 **	Climate neutral (all GHG) by 2050, proposed legislation
France	Covered by EU NDC **	Net zero GHG emissions by 2050
Germany	Covered by EU NDC **	Net zero GHG emissions by 2050, in policy document & legislation
India	33-35% reduction in emission intensity of GDP compared to 2005	
Indonesia	29% reduction below business as usual	
Italy	Covered by EU NDC **	Net zero by 2050, policy position
Japan	26% reduction below 2013	Net zero GHG by 2050, in policy document
Mexico	22-36% GHG reduction on business as usual	Under discussion
Russia	30% reduction below 1990	
Saudi Arabia	130MtCO _{2e} reduction on business as usual	
South Africa	Emission target of 398-614MtCO _{2e}	Net zero carbon economy by 2050, under discussion
South Korea	24.4% reduction below 2017	Net zero GHG by 2050, proposed legislation

⁴⁷ Energy and Climate Intelligence Unit Net Zero Tracker and UNFCCC submissions.

Turkey	21% reduction below business as usual	
United States	26-28% reduction on 2005 by 2025	Net zero by 2050, policy position

* Countries are encouraged to update NDCs ahead of COP26; targets may change as a result.

** EU countries submit a joint target covered by the EU NDC; the share of effort remains to be determined.

Summary: International circumstances

155. In summary, the analysis shows that Option 1, the do-nothing option, is not consistent with the UK's overall international climate change ambition. All options apart from 'do nothing' deliver emission reductions on a per capita basis that, if followed globally, would be consistent with the ambitions of the Paris Agreement. Relative to option 2, options 3 and 4 would fare more favourably from a global climate leadership perspective by delivering faster emission reductions and resulting in lower cumulative emissions to 2050.
156. All options apart from 'do nothing' are more ambitious than if global mitigation efforts were shared across countries or regions on the basis of estimates of cost-effective technical abatement potentials. However, they are less ambitious than if efforts were shared with historical contributions to emissions taken into account.

2.5 Quantified costs and benefits

157. This section presents results of the cost benefit analysis of different sixth carbon budget options across the pathways. Overall, the net present values of all the options are strongly positive for all pathways. Looser carbon budget options tend to have higher net present values. Details on the appraisal methodology can be found in Annex A.1.

Methodology summary

158. The appraisal is based on additional system costs, emissions savings and air quality impacts from UKTM model runs compared to baseline runs (Option 1).
159. The baseline is based on emissions projections as outlined in paragraph 33 and does not meet the 2030 NDC or 2050 Net Zero target, both of which act as constraints on emissions separately from the sixth carbon budget decision. Hence, not all costs and benefits presented in this section are additional to current government ambition or policy plans. However, the relative difference in cost and benefits between the different sixth carbon budget options are not impacted by this.
160. Additional system costs cover capital costs and finance costs (on an annualised basis), operating costs, network costs and fuel costs. Costs of hassle and disruption associated with the transition are not included. Some power sector costs are taken from the BEIS Dynamic Dispatch Model (DDM) and Distribution Network Model (DNM), which provides a more sophisticated cost estimate of the power sector than UKTM.
161. The benefits of abated greenhouse gas emissions, compared to the baseline, are monetised using HMG's carbon value series⁴⁸. High carbon values have been used (similar to the CCC's analysis) with the existing central value tested as a sensitivity. This reflects the fact that the current central carbon values, which are under review and are set on a target consistent basis, are likely to undervalue greenhouse gas emissions given

⁴⁸ Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal, <https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal>

that they are consistent with the UK's old decarbonisation target of 80% reduction in emissions by 2050.

162. In addition to carbon savings, benefits covered include fuel savings and natural capital improvements such as air quality benefits. Air quality impacts are monetised in line with the national values of the most recently air quality damage costs. Natural capital costs and benefits are particularly uncertain as their impacts are local. Since the specific policies to meet the sixth carbon budget are not yet known this analysis only provides a general assessment. Costs and benefits are discounted according to Green Book guidance of 3.5% p.a. with air quality impacts subject to a lower 1.5% p.a. health discount rate. As a sensitivity, this lower discount rate is also applied to emissions savings.
163. The UKTM model runs are illustrative of the technologies that may be required to cost effectively reach the sixth carbon budget options. The appraisal does not assume specific policy choices and there is a high degree of uncertainty around what policies will be used to meet the sixth carbon budget, and what their costs and benefits will be.
164. The appraisal period is 2020 to 2050, reflecting that achieving the sixth carbon budget depends on action taken in earlier carbon budget periods and, likewise, future carbon budgets will depend on action taken during the sixth carbon budget. The appraisal period does not represent the full period over which there will be costs of mitigating emissions or benefits from the UK's contribution to climate change mitigation. However, the analysis did not show that costs and benefits beyond 2050 would be significantly different across the sixth carbon budget level options.
165. As the purpose of this Impact Assessment is to support the decision on the sixth carbon budget level, the cost-benefit-analysis should not be interpreted as a full appraisal of the UK's decision to pursue a 2050 Net Zero target.

NPV summary across levels and pathways

Table 15: Net present values of the considered sixth carbon budget options across pathways

NPV (£bn)		Sixth carbon budget options		
		Option 2 1105Mt	Option 3 965Mt	Option 4 885Mt
Pathway	Core	289	266	211
	High CCS	330	292	249
	High resource	318	274	232
	CCS delay	176	127	67

166. Table 15 shows the net present values of the sixth carbon budget options for each pathway. All net present values are significantly positive. The ordering of the pathways is common across budget levels, with high CCS the pathway with the highest NPV and CCS delay the pathway with the lowest. Of the technology assumptions analysed, results are most sensitive to changes in availability and efficiency of carbon capture and storage.
167. This shows that the absolute impacts of the sixth carbon budget will depend on how the level is achieved. However, the relative impacts of the considered levels are not substantially impacted by the technology pathway. Therefore, the remaining analysis in this section focuses on the core pathway to illustrate the impacts of the different budget options, the main purpose of this Impact Assessment.

NPV summary across levels

168. Less ambitious sixth carbon budget levels have higher NPVs than more ambitious levels, indicating that the marginal cost of abatement is higher than the (high) carbon values. The differences between options are substantial in absolute terms, but smaller in relative terms: for example, the NPV for Option 2 is £23bn higher than Option 3 in the core pathway, but this is a difference of only 9%, with cost benefit ratios of 1.49 and 1.41 respectively.

Table 16: NPV breakdown by sixth carbon budget options, Core pathway only

	Costs and benefits 2020-2050 (£bn, discounted)	Option 2 Looser 1105Mt	Option 3 CCC level 965Mt	Option 4 Tighter 865Mt
Benefits	Total benefits	879	918	936
	Carbon savings	716	754	770
	Natural capital	5	5	5
	Air quality	36	35	34
	Fuel savings	121	123	127
Costs	Total costs	589	651	725
	Capital and finance costs	565	621	682
	Non-fuel operational costs	24	31	43

169. Table 16 shows the composition of the net present value across Options 2-4. The great majority of benefits are emissions savings benefits, with fuel savings, air quality improvements and other natural capital impacts constituting the remaining benefits. Annex A.5 provides a more detailed breakdown of the environmental impacts considered. Non-carbon benefits do not significantly differ between levels.
170. The vast majority of costs are additional capital costs, illustrating that the transition to net zero is primarily capital intensive. This is the case across all sixth carbon budget options. For the CCC level, additional operational costs amount to under 5% of total additional costs. Significant fuel savings are expected, offsetting 20% of additional capital costs.
171. In net cost terms and considering only the core pathway, accounting for capital costs, operational costs, and fuel savings, we estimate that the cost of meeting the CCC's recommended sixth carbon budget level will be equivalent to 1.6% of GDP in 2035. The comparable cost of meeting the Net Zero target would be 1.8% of GDP in 2050. This is within the envelope of 1-2% of GDP that has previously been estimated as the cost of meeting the UK's decarbonisation targets.

NPV sensitivities summary

Table 17: Summary of NPV sensitivities compared to central estimates

		Option 2 1105Mt	Option 3 965Mt	Option 4 865Mt
Central NPV		£289bn	£266bn	£211bn
Fuel prices	Low	£257bn -11%	£224bn -16%	£173bn -18%
	High	£305bn +6%	£276bn +4%	£251bn +19%
Carbon values⁴⁹	Current central series	£51bn -82%	£15bn -94%	-£46bn -122%
GDP growth	Low	£314bn +9%	£280bn +5%	£239bn +13%
	High	£256bn -11%	£219bn -18%	£166bn -20%
Environmental discount rate (applied to emissions savings)⁵⁰		£684bn +137%	£677bn +155%	£630bn +199%

172. The sensitivities shown above do not render any of the net present values negative, except that the tightest budget level (Option 4) has a negative NPV under the current central carbon value series. GDP growth and fuel prices have little impact on the relative NPVs of the three options, and change the NPVs by at most 19%. The positivity of NPVs is robust to optimism bias; in order for the net present value to be negative, additional system costs for the CCC level would have to rise by 41%.
173. The carbon values used to quantify the benefits of emissions reductions, and the reduction of the environmental discount rate to 1.5% both have a significant impact on the differences between the NPVs of the three levels, as well as their absolute size. Using a lower carbon value series (i.e. the current central series) causes NPVs to fall very significantly (by 94% for the CCC level) and the difference between the CCC and looser levels increases by £13bn, to £36bn. This reflects that decreasing carbon values makes abatement relatively less valuable and thus ambitious budget levels less attractive. Carbon values would need to be 61% higher than current high series for the CCC level to replace the looser level as the option with the highest NPV.
174. The environmental discount rate sensitivity removes the wealth element of the 3.5% discount rate for carbon savings by uplifting the carbon values by 2% annually. This reflects the potential insensitivity of the value placed on the environment to GDP growth, and results in future emissions reductions being valued at a higher rate. This significantly increases the magnitude of carbon benefits and reduces the difference between the CCC level (Option 3) and the looser level (Option 2) from £23bn to £7bn. The proportional difference between these two NPVs becomes very small, falling from 9% to 1%.

⁴⁹ The central NPVs use the current high carbon value series, reflecting that the UK's climate ambition has increased since these values were calculated. The low NPVs use the current central carbon value series.

⁵⁰ The central NPVs use the current Green Book guidance and discount monetised carbon savings by 3.5%. We tested a reduced discount rate for environmental project of 1.5% by removing the wealth element of the discount rate, mirroring the approach for valuing health benefits.

Summary: Quantified costs and benefits

175. In summary, the analysis shows significantly positive NPVs across all sixth carbon budget options. NPVs are higher for looser budget options and this holds true across different pathway assumptions and various sensitivities. The relative difference in NPV between the considered sixth carbon budget options is small (9% between Options 2 and 3) compared to the scale of uncertainty.

2.6 Unquantified cost and benefits - Section 10 and 13 impacts

176. Section 10 of the Climate Change Act sets out the matters that need to be considered for decisions relating to carbon budgets. Many of these matters are explored in more depth above, so this section covers all of these matters systematically and where needed references other relevant sections.

Scientific knowledge about climate change

177. The Climate Change Act requires that scientific knowledge be considered when setting carbon budgets. Climate science underpins the UK's 2050 target to reach net zero emissions. This target was advised by the Climate Change Committee as an appropriate share of global action to reach the Paris Agreement goal of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels, pursuing efforts to limit the temperature increase to below 1.5°C". Aside from do nothing, all the sixth carbon budget options analysed here are consistent with IPCC estimates of the emissions reductions required to meet this target.
178. However, there are large and persistent uncertainties around both the sensitivity of global temperatures to greenhouse gas emissions and the costs of adapting to varying temperature rises. These uncertainties tend to be greater in relation to higher levels of warming and greenhouse gas emissions, since we know less about global climates that are more dissimilar to today's. Worst case scenarios, in which global warming occurs quicker and with more consequences than we expect, are real and dangerous possibilities. Aversion to these tail risks, as well as the central projection, is a crucial pillar of the scientific argument for decarbonisation. Global emissions should therefore be reduced and stabilised at net zero as quickly as possible.
179. Total greenhouse gas emissions over time determine the UK's contribution to climate change. The levels of the sixth carbon budget that are analysed here imply only minor differences in future UK cumulative emissions which, because UK emissions are only a fraction of global emissions, means these differences have a very small impact on global emissions. However, given the potential impact of high UK climate ambition on other countries' policies and climate ambition, especially in the context of the UK's presidency at COP26 in 2021, more ambitious targets could meaningfully contribute to global efforts towards net zero (see section 2.4).
180. Irrespective of the sixth carbon budget level or the actions of the rest of the world, global temperatures will continue to rise to some extent and there will be costs of adapting to the consequences of climate change. These costs are highly uncertain and depend on the success with which global climate ambition is raised, emissions reductions are delivered and the UK is prepared for the impact of future climate change through, for example, using climate change risk assessments to inform infrastructure investment.
181. The carbon values used in the appraisal in section 2.5 do not represent the social damage cost of carbon. Rather they are based on a target-consistent approach, using estimates of the abatement costs that will need to be incurred to meet specific emissions

reduction targets. Thus, damage and adaptation costs are not directly considered. Due to the complexity of calculating costs of adaptation, a national assessment on adaptation costs in the UK does not exist. However, it is clear that the UK is already experiencing the impacts of climate change and the latest UK climate projections show an increased chance of warmer, wetter winters and hotter, drier summers along with an increase in the frequency and intensity of extremes⁵¹.

182. Therefore, ensuring that climate adaptation is integrated with carbon mitigation measures, policy making and investment for both sectoral and cross-cutting developments is necessary. Ensuring resilience is improved to a changing climate is required alongside the possible pathways to reduce greenhouse gas emissions and future climate scenarios.
183. As an example, it is estimated that proactive investment in the long-term resilience of England's water supply to drought over the next 30 years would cost approximately half that of short-term emergency measures for equivalent events⁵². Additionally, failure to adapt to climate change could make future maintenance of net zero more challenging. For example, future increased risks of drought present a potential challenge to woodland creation, and reduced aggregate productivity from warmer climates would increase carbon emissions⁵³.

Technology relevant to climate change

184. Technological circumstances are considered by modelling in UKTM. The model contains all technologies for which sufficient evidence is available. More details on the way in which UKTM considers evidence on technological circumstances are available in section 2.1, section 2.2 and in annex A.2. The costs of some low carbon technologies (e.g. offshore wind, solar PV, and electric vehicle batteries) have fallen faster than originally predicted. UKTM factors in future cost reductions in technologies but there is scope for costs to fall more quickly than assumed. This would reduce the capital costs of the transition to net zero.

Economic circumstances

185. The Climate Change Act requires that economic circumstances be considered. In particular, the impact of the decision on the economy and the competitiveness of particular sectors of the economy. A key aspect in evaluating the economic effect is the counterfactual used as a baseline reference.
186. The 2006 Stern Review estimated that the cost of global inaction on climate change significantly outweighs the expected cost of coordinated global action. Without effort to tackle climate change, the Stern Review predicted that the loss of GDP from climate change could cost the global economy significantly more than the global cost of action to stabilise atmospheric concentrations of greenhouse gases.
187. In comparison, as set out in the HMT Net Zero Review Interim Report⁵⁴, within the context of global action on climate change the net effect on UK economic growth is likely to be relatively small, including positive and negative impacts via multiple channels, but highly uncertain. The scale, distribution and balance of new growth opportunities and challenges will depend on the policies brought forward to meet commitments. As this

⁵⁰ <https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Overview-report.pdf>

⁵² Preparing for a drier future, National Infrastructure Commission, 2018, <https://nic.org.uk/studies-reports/national-infrastructure-assessment/national-infrastructure-assessment-1/preparing-for-a-drier-future/>

⁵³ Based on information presented in Economics of Climate Resilience, Agriculture and Forestry Theme: Forestry, 2013, <http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=18016>

⁵⁴ <https://www.gov.uk/government/publications/net-zero-review-interim-report>

Impact Assessment is policy agnostic, quantitative macro-economic modelling has not been carried out.

188. The impacts of the sixth carbon budget on the UK economy will depend on the specific policies introduced to meet the budget and the relative action of other countries, rather than on the level of the sixth carbon budget per se. Therefore, this Impact Assessment provides an overview of the important factors that will determine economic impacts, and the key methods of managing risks, rather than an estimation of aggregate or sectoral impacts. The vital underpinning of all policies will be that they seek to maximise a market-led and economically efficient decarbonisation, limiting state intervention to circumstances where market failures mean it is necessary.
189. Investment is a vital component of productivity growth, and significant investment will be necessary to achieve the sixth carbon budget. Policies that induce this investment must seek to ensure that it is genuinely additional. There is a risk that government investment in decarbonisation could 'crowd out' alternative private and potentially more productive investment, in turn lowering growth, particularly in areas where the supply chains struggle to scale up to meet the increased demand for capital goods. There is some evidence that stricter environmental regulation may incentivise greater R&D spend that more than offsets the costs of regulation compliance⁵⁵. However, there are risks from additional regulation, particularly in the short run, which may act as a drag on productivity.
190. The exact effect of investment on growth will depend on assessing both the specific policies but also the timing within the economic cycle, with counter-cyclical investment potentially supporting demand and ultimately growth when the economy is operating below capacity.
191. Increased demand for decarbonisation technologies and policies that incentivise low-carbon innovation or penalise high-carbon technologies can foster innovation that increases domestic competitiveness and global comparative advantage for some UK industries, providing potential export opportunities. But there will also be risks to sectors and industries susceptible to competitiveness impacts, particularly those that are trade-exposed or carbon intensive. Where UK firms lose market share to international firms with lower environmental standards, there is a high risk of carbon leakage. There is little empirical evidence of this occurring in the UK as yet, but risks may increase as further policy is implemented. Vulnerable firms may include, for example, those for whom energy is a significant proportion of the cost base or a key differentiator in costs of production with competitors. Decarbonisation of these sectors could require additional investment which, in many cases can increase operating costs, though these costs can be offset at least in part by greater levels of energy efficiency.
192. Historically, the UK's approach to mitigating competitiveness impacts and carbon leakage risk has been through issuing free allowances under the EU ETS. This approach has been carried over to the UK ETS, and possible changes to free allowances are currently under review. BEIS also provides compensation to certain energy intensive industries for the indirect emission cost due to the UK ETS and some sectors receive a reduction in energy consumption tax via Climate Change Agreements. The eventual impact of decarbonisation on firms at risk will depend on future policy development, particularly relating to the UK ETS.
193. The magnitude of competitiveness effects in international markets are dependent on global climate ambition as well as domestic policy. If the UK continues to have a world

⁵⁵ UK business competitiveness and the role of carbon pricing, p24-25 <https://www.gov.uk/government/publications/business-competitiveness-in-industrial-sectors-and-the-role-of-carbon-pricing-policy-in-the-uk>

leading climate ambition, competitiveness effects may be larger. However, if other countries, particularly the UK's trading partners, increase their industrial decarbonisation ambition in line with the UK's, and face similar additional costs, then competitiveness effects will be smaller. Similarly, where the UK's path to net zero creates export opportunities for UK businesses, the size of these will depend on the actions of the rest of the world. High global climate ambition will result in a large market for decarbonisation technologies but may also result in more global competition in those markets.

Fiscal circumstances

194. The Climate Change Act requires that fiscal circumstances should be considered, in particular the likely impact of the decision on taxation, public spending and public borrowing. The modelling in section 2.2 estimates the costs to the whole system of achieving the carbon budget options, but it is agnostic to the type of policy levers that will be introduced which will determine the fiscal impacts i.e., how costs will be distributed between the public and private sectors and how the public portion of the costs will be funded, which are subject to future government decisions.
195. The transition to net zero and consequent structural changes in the economy will have implications for the UK's public finances and fiscal sustainability:
- The HMT Net Zero Review Interim Report identified £37bn of direct tax receipts in 2019/20, primarily fuel duty, that would be eroded through decarbonisation as the tax base reduces for high-carbon technologies and economic activity incompatible with decarbonisation.
 - Impacts on specific economic channels will also have fiscal consequences. For example, changing energy prices will affect aggregate inflation as measured by RPI or CPI, and will in turn impact tax revenues, public spending and the costs of servicing government borrowing as taxes, welfare benefits and gilt rates are all linked to RPI and CPI.
 - The fiscal impact of the transition will also be affected by the overall macroeconomic impact, but as set out above this is likely to be small. There is uncertainty as to how the macroeconomic impact will materialise over time. Nevertheless, changes to the sectoral composition of the economy may alter the fiscal position.
 - Decarbonisation will mean significant changes for high polluting sectors and industries that may affect tax revenue from these sectors, as well as new tax revenues from growth in low-carbon sectors. The net balance will depend on both the speed of growth and the tax intensity of these sectors.
196. The fiscal pressures will need to be managed within the context of many other pressures such as a higher debt stock as a result of the covid-19 pandemic and an ageing population. The policy design and the relative mix between the different type of domestic policy levers (e.g., regulation, public spending, financial incentives, taxes, and information provision) will be important determinants of the fiscal impacts.
197. Whilst the exact policy decisions are not known, as set out in the HM Treasury Net Zero Review Interim Report, the vast majority of investment necessary to deliver the sixth carbon budget and net zero will be undertaken by the private sector.

Social circumstances

Fuel poverty

198. The Climate Change Act requires that social circumstances be taken into account, in particular the likely impact of the decision on fuel poverty.
199. The costs of the sixth carbon budget, and decarbonisation more generally, will ultimately be borne by households either in the current generation or by future generations when any borrowing to finance decarbonisation will need to be repaid. Within the current generation, households can finance decarbonisation directly through their own expenditure on low-carbon technology or indirectly via taxation to support government spending, through costs on business being passed-through into consumer prices or from costs being passed through into wages and dividends.
200. As part of this Impact Assessment modelling has also been carried out to provide an estimate of potential impacts on wholesale and retail electricity prices. Illustrative scenarios are assessed using BEIS's Dynamic Dispatch Model (DDM) and BEIS's Average Prices and Bills model (APBM). The modelling looks at the implications of future electricity generation mixes but assumes there is no change in current market or policy structure. These illustrative scenarios are therefore subject to considerable uncertainty and use several simplifying assumptions⁵⁶. Changes to these assumptions could have considerable impacts on prices.
201. The results focus on electricity price impacts of the sixth carbon budget option consistent with the CCC recommended level (Option 3). There is insufficient policy detail covering energy demand to appropriately model bill impacts. Benefits from energy efficiency measures which affect consumption levels are not considered as they are only realised through bill impacts. Final bill impacts may show different results to price impacts due to changes in demand from energy efficiency.
202. The overall impact of the sixth carbon budget decision on households will depend on future policies. However, compared to the do nothing option, decarbonisation would likely add upward pressure to electricity prices and heating costs, but lower transport fuel costs (reflecting the greater efficiency of EVs) based on current market and policy structures. Future transport and heating costs, if electric, may form a significant part of a household's electricity bill. These have not been considered in detail below due to a lack of certainty in the supporting policy framework. Precise bill impacts for individual households will also depend on several additional factors including consumer characteristics, fuel choices and policy eligibility.
203. Over the sixth carbon budget period retail electricity prices are generally higher for the CCC's recommended budget option compared to the baseline. An increase in Contracts for Difference (CfD) support costs and transmission costs linked to increased renewable deployment largely drives higher retail prices. Lower wholesale prices due to higher renewable generation slightly offsets this increase. However, the increase in household retail electricity prices is less than 5% for most pathways.

⁵⁶ The modelling includes the following assumptions:

- Hydrogen wholesale costs are assumed to be equal to gas wholesale costs
- Current supply side policy support mechanisms, such as the CfD and Capacity Market, remain unchanged and alternative funding models are not considered
- Additional policy cost associated with supporting measures that lead to increased demand (e.g. electrification of transport and heat) are not accounted for as they are subject to future funding decisions

204. Energy Intensive Industries that are currently exempt from a large proportion of CfD support costs would face lower prices if these exemptions remain in place. They would benefit from lower wholesale costs but would not face higher CfD payments.
205. Price impacts increase over the sixth carbon budget period but begin to plateau by the early 2040s and are broadly consistent across all pathways apart from the CCS delay pathway which implies greater impacts across all consumers.

Table 18: Average estimated impact on electricity retail prices for different consumer groups, compared to the counterfactual over the period 2033-2037, consistent with Option 3 (CCC level)

Illustrative consumer type	Core	High CCS	High Resource	CCS Delay
£2020/MWh				
Household	+6 (3%)	+7 (4%)	+7 (4%)	+17 (10%)
Medium business user⁵⁷	-0.5 (-0.5%)	+0.5 (0.5%)	+1 (1%)	+3 (2%)
Energy Intensive Industry with all current policy support⁵⁸	-2 (-3%)	-2 (-3%)	-2 (-2%)	-11 (-15%)
Energy Intensive Industry with no policy support⁵⁹	+1 (1%)	+2 (2%)	+2 (2%)	+6 (6%)

206. The impact on fuel poverty of electricity prices rising by less than 5% would be relatively small and moderated by higher levels of energy efficiency in the housing stock. By 2030 we expect all fuel poor households in England, as far as reasonably practicable, to be living in a home rated energy efficiency Band C or better, in line with the statutory fuel poverty target⁶⁰. Scotland, Wales and Northern Ireland have their own fuel poverty targets and are also working to improve the energy efficiency of their building stock.

Public engagement

207. Achieving the net zero target and any of the sixth carbon budget options will have a significant impact on people's lives, requiring action from everyone in society - people, businesses, and governments. The analysis on the level of the sixth carbon budget has not directly been informed by specific public consultation or deliberation exercises, although the CCC considered views and recommendations of the Climate Assembly UK in its advice to government.
208. As plans are developed for meeting the sixth carbon budget and reaching net zero emissions by 2050, government will continue to engage the public on the changes that are needed to develop ambitions, building on existing engagement programmes and exploring how to support individuals to make sustainable choices.

⁵⁷ Assumed to consume between 2,000 and 19,999MWh per year

⁵⁸ Assumed to consume between 40,000 to 160,000MWh per year, qualify for 85% exemptions from renewables obligation, feed-in-tariffs and contracts-for-difference support costs, and 60% compensation from indirect carbon costs (emissions trading scheme and carbon price support).

⁵⁹ Assumed to consume between 40,000 to 160,000MWh per year

⁶⁰ Fuel Poverty (England) Regulations 2014 <https://www.legislation.gov.uk/ukdsi/2014/9780111118900/contents>

Distribution of costs during the net zero transition

209. The distribution of the costs and opportunities of net zero across society will depend on future policy decisions. The HM Treasury review is examining the costs of decarbonisation, including how to achieve the transition to net zero in a way that works for households, businesses and public finances, as well as the implications for UK competitiveness. In December 2020 interim findings of this report were published and the final report and recommendations of the review will be published this year.
210. Initiatives such as the Green Jobs Taskforce⁶¹, the North Sea Transition Deal, and sector deals on nuclear, offshore wind and automotive will help to create good quality green jobs across the country and support the most exposed workers and sectors to transition to net zero.

Energy policy

211. The Climate Change Act requires the consideration of energy policy, and in particular the likely impact of the budget level decision on energy supplies and the carbon and energy intensities of the economy.
212. The carbon and energy intensities of the economy are measured as the ratio of total energy use or emissions of greenhouse gases to the value of the UK's economic activity. Aligned with the scope of this Impact Assessment set out in section 1.4, the emissions intensity of the UK economy in 1990, as measured through territorial emissions was 683tCO_{2e}/GDP£2019m, with an energy intensity as measured through final energy demand of 1333MWh/GDP£2019m. In comparison, the emission and final energy intensity of the UK economy is forecasted to be around 146tCO_{2e}/£GDP2019m and 545MWh/GDP£2019m respectively in 2035, in the do-nothing baseline.
213. Table 19 below presents the impact on the energy and emissions intensity of the economy under the sixth carbon budget options compared to 1990 and the baseline.⁶² Under the do-nothing baseline, the emissions intensity of the UK economy is expected to have fallen by 79% relative to 1990. Meeting the sixth carbon budget options through domestic emissions reduction could reduce the emissions intensity by around 90% compared to 1990.⁶³ Relative to 1990 levels, energy intensity falls by 59% in the baseline and around 67% in Options 2-4.

Table 19: Carbon and energy intensity of the sixth carbon budget options

	1990	Baseline Option 1 2035	Option 2 2035	Option 3 2035	Option 4 2035
GDP emission intensity (tCO_{2e}/GDP£m2019)	683	146	77	67	62
% reduction on 1990 carbon intensity		-79%	-89%	-90%	-91%
GDP energy intensity (MWh/GDP£m2019)	1333	545	446	440	435
% reduction on 1990 energy intensity		-59%	-67%	-67%	-67%

⁶¹ <https://www.gov.uk/government/groups/green-jobs-taskforce>

⁶² Latest OBR GDP growth assumptions are used to estimate GDP in 2035. Short-term forecast published alongside Spending Review 2020, and long-term forecast published in March 2020. Final energy demands are consistent with core long-term pathways presented in section 2.2.

⁶³ This analysis assumed no impact on economic growth from undertaking actions to meet the level of carbon budget six. Depending on the scale of impacts discussed in the section on Economic circumstances these values could be higher (in case of negative impact on economic growth) or higher (in case of negative impact on economic growth).

214. Energy security is about ensuring secure, reliable and uninterrupted supply of electricity to consumers. The government is committed to ensuring there is secure supply for consumers whatever the energy mix.
215. The precise impact of the sixth carbon budget level on each of these elements will depend on what energy policies are implemented as a result of the carbon budget level. However as highlighted in section 2.3, delivering any level of the sixth carbon budget will require a substantial increase in electrification (which rises for tighter sixth carbon options) and the simultaneous deep decarbonisation of electricity supply which carry their own security of supply risks and system operability issues. Electrification, along with other measures considered as part of the technology mix, has the potential to reduce demand for gas, coal, oil and transport fuels which could improve security of supply by diversifying away from primarily imported fossil fuels.

Differences in circumstances between England, Wales, Scotland and Northern Ireland

216. Under the Climate Change Act the UK Government is required, prior to setting the sixth carbon budget, to take into account representations made by the Scottish Government, Welsh Government and the Northern Ireland Executive. Collectively, the DAs accounted for 22% of UK emissions in 2018.⁶⁴ Their territories are covered by the Act, but they have also set their own targets through their own legislative frameworks. These have been set broadly in line with the legally binding UK net zero target.
217. Representations from Devolved Administrations on the UK's sixth carbon budget are outlined in annex A.6. In summary:
- Scotland: The Scottish Government supports the recommendation of the CCC (Option 3), as the minimum level that the sixth carbon budget should be set, including emissions from international aviation and shipping, and that the fifth carbon budget should be amended to align with the 2030 NDC level.
 - Wales: The Welsh Government is of the view that the UK should set the sixth carbon budget level recommend by the CCC (Option 3), including emissions from international shipping and aviation, and that the fifth carbon budget should be amended to align with the 2030 NDC level.
 - Northern Ireland: Northern Ireland is supportive of the CCC's recommended level for the sixth carbon budget (Option 3).
218. The government has considered these views when reaching its decision on the sixth carbon budget and has proposed to set the budget at the level recommended by the CCC (Option 3), inclusive of emission from international aviation and shipping, which was supported by all Devolved Administrations.
219. The unique characteristics of each nation will have a bearing on the technical maximum abatement potential in that nation and on the measures that will deliver emissions savings. For instance, agriculture accounts for a larger proportion of the economy in Northern Ireland, Wales and Scotland than in England, and so will account for a higher proportion of emissions than the UK average.
220. The government has worked to ensure that the estimates of technical potential for emissions reductions during the sixth carbon budget period presented in this Impact Assessment take account of the best available data and evidence. UK wide data sets

⁶⁴ Note: 1990-2019 UK GHG emissions published Feb 2021. Equivalent DA GHG emissions estimates due to be published June 2021.

have been used where possible. However, for some sectors assumptions have been made to adjust for nation-specific impacts.

International circumstances

221. The Climate Change Act requires that circumstances at the European and international level are taken into account. This is covered by section 2.4, which assesses the ambition of the options for the sixth carbon budget level in the context of global action on climate change and international commitments on climate change mitigation.

International Aviation and Shipping emissions

222. The Climate Change Act requires that the estimated amount of reportable emissions from international aviation and shipping for the budgetary period is taken into account. This is covered by section 1.5 which covers the accounting basis with respect to IAS, and section 2.2, which covers the sectoral emissions breakdowns based on the modelled pathways.

Other factors: Natural Capital

223. As an additional factor, this section considers the Natural Capital impacts of the decision on the level of the sixth carbon budget.

224. In line with HM Treasury Green Book guidance, a natural capital perspective is taken. Pathways and policies which negatively impact natural capital are not in line with sustainable development and risk degradation of natural assets. Qualitative impacts to natural capital are detailed in this section. Qualitative impacts to natural capital are detailed in this section, and annex A.5 provides more detail on the breakdown of quantified and qualitative natural capital impacts already covered in section 2.5.

225. The independent Natural Capital Committee, established in 2012, has defined natural capital as ‘those elements of the natural environment which provide valuable goods and services to people’⁶⁵. Nature underpins our economy and society: the energy, food and water we consume; the air we breathe; our access to green space; and biodiversity, which is crucial in underpinning all our ecosystem and abiotic services, and in maintaining ecological function. Nature is a major economic sector in its own right – as a productive asset it provides market and non-market services of £29 billion each year⁶⁶.

226. There are likely to be significant positive and negative impacts to natural capital from meeting each of the sixth carbon budget options. Impacts will largely be determined by the specific policies chosen to meet the sixth carbon budget level and may be localised or time bound. In-depth exploration of the natural capital impacts of specific policies and policy mixes for the sixth carbon budget will need to be undertaken to ensure trade-offs are managed and impacts mitigated. The following paragraphs summarise likely impacts for each natural capital pillar. Further details are found in Annex A.5.

227. **Land Use trade-offs:** the rapid and unprecedented rate of land use change resulting from implementation of the more stringent afforestation and biomass scenarios (up to 103 kha/yr) represents a high risk to natural capital. It is likely that there would need to be trade-offs impacting food production, biodiversity, landscape and water resources to accelerate to and maintain such levels of land use change. Given that local community

⁶⁵ See <https://www.gov.uk/government/groups/natural-capital-committee> The Natural Capital Committee is an independent advisory body, set up in 2012. It provides advice to the government on the state of England’s natural capital - that is, our natural assets include forests, rivers, land, minerals and oceans.

⁶⁶ ONS (2020). Environmental Good and services sector estimate

objection to planting schemes is already common, acceleration on this scale would also be expected to meet negative public reaction.

228. **Recreation and amenity:** meeting the sixth carbon budget is likely to have positive impacts for recreation and amenity. However, there may be localised negative impacts.
229. **Air quality:** meeting the sixth carbon budget will reduce emissions of several air pollutants. However, there is a significant risk that specific policies chosen could be detrimental to government obligations (Emissions Ceilings) and wider commitments. There is a risk that the health of the public may also be negatively impacted, in some cases and in some areas. Ongoing consideration of the potential impacts of air pollutants at a local scale is needed at policy level.
230. **Water:** meeting the sixth carbon budget may have positive and negative impacts on water quality and quantity, and these should be assessed on a case-by-case basis and mitigating actions taken where necessary, including around intensification of agriculture, anaerobic digestion, and low carbon technologies such as nuclear, CCS and hydrogen production.
231. **Biodiversity:** overall, the sixth carbon budget can be positive for biodiversity (marine and terrestrial), including for habitat restoration, connectivity, resilience and reducing ecological stress caused by climate change. However, there may be spatially and climatically explicit impacts of policies which should be considered, including around low carbon technologies, GGRS, shipping and agricultural intensification.
232. **Raw materials, resource efficiency and waste:** materials are finite. Some low carbon technologies have specific reliance on critical raw materials, many of which are rare, found in unique locations and in high demand globally. Policies which improve resource efficiency as well as reducing waste reduce both embodied product and waste emissions.

3 Conclusion

233. Recommending a budget level for the sixth carbon budget requires the consideration of all five assessment criteria in the round, including taking into account specific factors set out in the Climate Change Act, as well as the advice of the Committee on Climate Change and the representations of the Devolved Administrations.
234. Considering all assessment criteria in the round, including specific factors set out in the Climate Change Act, the proposed option for the sixth carbon budget level is 965MtCO_{2e}, Option 3. This option is the recommended level by the CCC and the preferred option of the Devolved Administrations. The high level of ambition supports the overall policy objective of mitigating the potentially catastrophic effects of climate change, while the more ambitious Option 4 could lead to non-economical outcomes. Option 3 is more challenging than Option 2 from a technical feasibility and delivery perspective, but the analysis shows it is technically feasible to achieve and has a strongly positive NPV. Option 3 is also in line with an ambitious contribution to global efforts towards meeting the Paris Agreement temperature goal and strengthens the UK position in pushing for higher ambition from other countries. Whilst the costs of this option are higher and the NPV is smaller than those of Option 2, these relative differences are within the uncertainty ranges and in the whole outweighed by the other assessment criteria.
235. Table 20 provides a summary of all the criteria that have been considered.

Table 20: Summary of the Assessment criteria across the different options

Consideration	Budget level option			
	Option 1	Option 2	Option 3	Option 4
Budget level (in MtCO _{2e})	2100	1105	965	885
CCC advice	Highly insufficient to meet the CCC's balanced pathway to Net Zero.	In line with CCC's <i>Headwinds</i> scenario and less ambitious than the recommended balanced pathway.	CCC recommended level.	In line with CCC's <i>widespread innovation scenario</i> and more ambitious than the recommended level.
DA views	Not consistent with DA views	Not consistent with DA views	Budget level endorsed by all Das	Scottish Government view Option 3 as minimum
Assessment criteria				
1) Long-term pathways and technological feasibility	Budget is technically feasible, but the pathway does not meet the UK's 2050 target and is inconsistent with the UK's 2030 NDC.	Budget is challenging and technically stretching but feasible and in line with the 2050 target.	Budget level is technically feasible and in line with 2050 target, but more stretching and more technical challenging than Option 2.	Budget level is technically feasible, but more technical challenging than Option 3 and might lead to non-economical outcomes.

Consideration	Budget level option			
	Option 1	Option 2	Option 3	Option 4
Budget level (in MtCO _{2e})	2100	1105	965	885
2) Delivery implications	No delivery implications , as no additional abatement action beyond current policies necessary.	Budget level is stretching to deliver with barriers of all types to overcome.	Budget level is more challenging to deliver than Options 2 and more reliant on overcoming barriers.	Budget level is more challenging to deliver than Options 3 and more reliant on overcoming barriers.
3) International circumstances	Insufficient to deliver the UK's international ambition.	Budget level is consistent with Paris Agreement temperature goal.	Budget level is consistent with Paris Agreement temperature goal; likely to be perceived as internationally ambitious by delivering faster emission reductions and resulting in lower cumulative emissions than Option 2.	Budget level is consistent with Paris Agreement temperature goal; likely to be perceived as very internationally ambitious by delivering faster emission reductions and resulting in lower cumulative emissions than Option 3.
4) Quantified cost & benefits				
Indicative NPV of core scenario 2020-2050 (£bn, 2019), range shown in brackets	0	289 (176-330)	266 (127-292)	211 (67-249)
Composition of NPV:				
Costs of core scenario 2020-2050 (Present Value, £bn, 2019),	0	589 (554-710)	651 (622-775)	725 (693-865)
Benefits of core scenario 2020-2050 (Present Value, £bn, 2019)	0	879 (873-886)	918 (896-918)	936 (927-941)
5) Unquantified costs and benefits and wider impacts	<p>With the right policies there is potential for greater unquantified economic benefits for the tighter budget options, such as innovation and export opportunities.</p> <p>Those factors that must be considered under the Climate Change Act that are not covered above (climate change science, economic, social and fiscal circumstances, energy policy) are summarised in table 21.</p>			

Table 21: Summary of Climate Change Act Section 10 factors

Climate Change Act factors	
Climate change science	Options 2-4 are potentially consistent with action to meet the UK's 2050 target but Option 1 is not. Since the 2050 target was set as an indicative and appropriate UK contribution towards the Paris climate goals, Option 2-4 could plausibly be consistent with the stated climate ambition. Differences between Options 2, 3 and 4 are minor compared to the size of global emissions and uncertainty over the effects of GHG emissions.
Relevant technology	All considered sixth carbon budget options are technically feasible with tighter budgets more challenging. Early deployment can help develop emergent technologies, and keep options open for later decarbonisation, thereby reducing the risk of failing to meet the 2050 target. See assessment criterion 1.
Economic circumstances	The impacts of the sixth carbon budget on the UK economy will depend on the specific policies introduced to meet the budget and the relative action of other countries. As set out in the HMT Net Zero Review Interim Report, the combined aggregate macro-economic effect of UK and global climate action on UK economic growth is likely to be relatively small, include offsetting positive and negative impacts via multiple channels, which we would not expect to vary significantly based on the options considered in this Impact Assessment.
Fiscal circumstances	The details of policies to meet the sixth carbon budget are not yet determined, so these impacts are unknown, although the relative mix between regulation tax and subsidy will be an important determinant.
Social circumstances	Impacts on fuel poverty are highly uncertain and will depend on the specific policies and levers used to implement budgets. Climate policies can affect fuel poverty targets through energy prices and by affecting the energy needs of households (e.g., through improved insulation of buildings).
Energy policy	Impacts on energy policy of different levels of the sixth carbon budget will depend largely on the policies and levers used to meet the budget level.
Differences in circumstances between England, Wales, Scotland and Northern Ireland	Impacts of different levels of the sixth carbon budget will depend largely on the policies and levers used to meet the budget level. Responsibility for emissions reductions in several sectors is devolved to the individual nations. The views of the devolved nations on the level of the sixth carbon budget has been considered.
International circumstances	See assessment criteria 3.
International aviation and shipping	In line with the CCC's advice, IAS emissions will be legally included in the sixth carbon budget.
Other factors	
Natural capital	No definitive conclusion regarding the level of the sixth carbon budget. All the sixth carbon budget levels present benefits and risks to sustainable development, and these will be dependent on policies chosen.

Annexes

A.1 Assumptions

236. The analysis in this Impact Assessment is consistent with standard government appraisal methodologies as laid out in HM Treasury’s Green Book⁶⁷. Specific supplementary guidance on valuation of energy use and greenhouse gas emission for appraisal has been applied for estimates of the scale and value of fuel and emission impacts⁶⁸. A summary of the overarching assumption set used throughout the Impact Assessment (unless otherwise stated) is given in the following table.

Table A1: Summary of appraisal assumptions

Carbon values	Abated greenhouse gas emissions are monetised using the existing high carbon value series, in addition to the existing central values as a sensitivity. This reflects the fact that the current central carbon values are likely to undervalue greenhouse gas emissions now the UK has increased its domestic and international targets, though the scale of undervaluation is still unclear. HMG is planning to review the carbon values during 2021.
Air quality	Air quality impacts are monetised in line with the national values of the most recently air quality damage costs. Natural capital costs and benefits are particularly uncertain as their impacts are local, but as the specific policies to meet the sixth carbon budget are not yet known, our analysis can only provide generalised assessment, mainly using national average damage costs.
Fuel prices	Fossil fuel prices are taken from the BEIS Fossil Fuel Price Assumptions 2019. The high and low series are used as sensitivities.
Economic growth	GDP growth assumptions have been aligned to the OBR long-term forecasts published in March 2020 and the short-term central forecast published in July 2020.
Price base	The price base is 2019 for all values.
Appraisal period	The appraisal period is 2020 to 2050.
Discounting	Costs and benefits are discounted according to Green Book guidance of 3.5% p.a. and air quality impacts also subject to a 2% p.a. health uplift. As a sensitivity, this health uplift is also applied to carbon savings.

⁶⁷ Green Book: appraisal and evaluation in central government, <https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government>

⁶⁸ Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal, <https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal>

A.2 UK TIMES model

237. For this analysis, model version v1.2.4 has been used. Quality assurance of the model has included a review of assumptions by relevant stakeholders.
238. UK TIMES (UKTM) is a technology-rich (approximately 2000 technologies) modelling tool which offers insight about some of the key interactions and future decision points for a complex and competing UK energy system. It provides information about the roles that technologies and resources could play under different pathways. UKTM uses a linear optimisation solver to identify the system that meets exogenous energy service demands with the lowest overall discounted system cost, subject to constraints such as GHG targets and build rate limitations.

Table A2: Summary of UKTIMES sectoral assumptions

Sector/Area	Assumptions summary
Carbon targets / values / accounting	GHG emissions trajectory - the model is constrained to: <ul style="list-style-type: none"> • Not exceed the projected EEP emissions level for carbon budgets 2-4 • Not exceed UK Nationally Determined Contribution for 2030 and the Net Zero target for 2050. • Over carbon budgets 6-8 different emission trajectories have been tested.
Pathways	Recognising the uncertainty associated with long-term modelling 4 net zero consistent whole-system pathways have been developed, representing different technology availability and resource conditions. All the sixth carbon budget emission level options are tested against each pathway. <p>These pathways are described in section 2.2.</p>
Resources, Refining & Fuel Manufacture (fossil fuels, hydrogen, bioenergy)	Fuel demand by sector is calibrated to DUKES (2012) 2010 statistics with alignment to the BEIS Energy Demand Model fuel use for electricity. <p>Bioenergy:</p> <ul style="list-style-type: none"> • Bioresource feedstock availability import inputs are from the Bioenergy Feedstock Availability Model⁶⁹, • Bioenergy crops planting rate at 53kha by 2035, deployment data provided by Defra and the Forestry Commission. <p>Hydrogen:</p> <ul style="list-style-type: none"> • Hydrogen production efficiencies and costs are aligned with the HSOP Hydrogen Supply Chain Evidence publication (Nov 2017). • Hydrogen production technology growth rates set at 10%, with a cumulative new capacity per year limit of 42 TWh. • Future import opportunities for liquid hydrogen are highly uncertain, therefore, this option was switched off for three of the four net zero pathways. There are options for imports other than liquefied hydrogen (e.g., ammonia, liquid organic hydrogen carriers) which have not been considered in this analysis.

⁶⁹ <https://www.gov.uk/government/publications/uk-and-global-bioenergy-resource-model>.

	<p>Fossil fuels:</p> <ul style="list-style-type: none"> Fossil Fuel prices from the BEIS Fossil Fuel Price Assumptions 2019
CCS	<p>There are 5 distinct types of CCS in UKTM: industrial, biogas (BECCS), power generation, hydrogen production, direct air capture (DAC).</p> <p>Start dates: CCS available for hydrogen, power, industry from 2025; Power BECCS from 2030, Hydrogen BECCS/DAC from 2035.</p>
Power	<p>Electricity generation technology assumptions (costs, existing stock, retirements, build rates, etc.) have been aligned as closely as possible with the BEIS Levelised Cost Model 2020⁷⁰ and Dynamic Dispatch Model 2020.</p>
Transport	<p>The transport sector has 9 vehicle types, all of which have a variety of abatement opportunities at different costs:</p> <ul style="list-style-type: none"> Car Bus Two-wheel Light goods vehicle Heavy good vehicle Rail passenger Rail freight Aviation - domestic & international Shipping - domestic & international <p>Car and LGV assumptions were sourced from DfT analysis based on Element Energy's ECCo Cost and Performance Database. HGV assumptions were sourced from Element Energy H2SM model.</p> <p>Road and rail demand is provided by the DfT from the National Transport Model. Road demands for the sensitivity analysis are taken from BEIS' Shadow National Transport Model up to 2040.</p> <p>Shipping data is based on modelling commissioned by the DfT⁷¹. The international shipping estimates have been adjusted downwards by 50%, based on the CCC advice report, to account for the difference between an activity based and a bunker fuel based accounting methodology.</p> <p>Aviation data on fuels, efficiency, and demand come from DfT aviation forecasts. Modelled UKTM aviation pathways are aligned with DfT's baseline forecast with a 5% minimum on biofuels in 2050, whilst the UKTM shipping pathways are based on Scenario D in the modelling commissioned by DfT. Given these pathways are near fixed in UKTM, the modelled outcomes for aviation and shipping do not reflect the full range of uncertainty.</p>
Residential buildings	<p>The housing stock is represented as five dwelling types – existing solid wall house, existing cavity wall houses, existing solid wall flat, existing cavity wall flat, and new build.</p>

⁷⁰ <https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020>

⁷¹ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/816018/scenario-analysis-take-up-of-emissions-reduction-options-impacts-on-emissions-costs.pdf

	Demand is based on a variety of NHM, DUKES, Energy Consumption in the UK (ECUK), Energy Demand Model (EDM) 2019 (including the updated OBR forecasts) and ONS, depending upon the particular driver.
Commercial/public buildings	The commercial/public buildings sector represents all non-domestic and non-industrial buildings in the UK. The model represents two categories of building: high energy consumption and low energy consumption.
Industry	<p>Annual demand profile aligned with driver assumptions underlying EDM 2019 adjusted for OBR forecasts.</p> <p>Industry service demand drivers largely based on Gross Value Added numbers in BEIS Energy and Emissions Projections.</p> <p>The subsectors within industry are modelled in two ways:</p> <ul style="list-style-type: none"> • Process-oriented: actual production processes are represented, and demand commodities are specified as physical goods (in Mt): <ul style="list-style-type: none"> o Technology assumptions are primarily taken from the Usable Energy Database (UED) for the UK industrial sector, which was developed in the scope of the UKERC project “Industrial Energy Use from a Bottom-Up Perspective”, Griffin et al. (2013)⁷². o Used to model iron and steel, cement, paper and part of chemicals sector. • Energy service demand based: demand for commodities are specified in terms of energy demand (in PJ) and processes such as high/low temperature, drying and refrigeration are modelled: <ul style="list-style-type: none"> o Base year Data (2010) on energy demand is taken from the ECUK (2012) and technology assumptions are mainly adapted from UK MARKAL. o They are used to model non-ferrous metals, other non-metallic minerals, food, drink and tobacco, other industries and part of chemicals sector.
Agriculture – crops, livestock, transport, heat, waste	Emissions from agricultural livestock and crop cultivation are from Defra FAPRI modelling. A flat emissions rate is assumed after 2040.
LULUCF – forestry, soils, land-use & land-use change	<p>Baseline GHG inventory projections are taken from projections by the Centre for Ecology and Hydrology’s LULUCF projections to 2050 and based on EEP 2019 including an adjustment for peatland emissions as described in section 1.4.</p> <p>Maximum afforestation / tree planting rate per annum at 30kha from 2030 provided to BEIS by the Forestry Commission are consistent with the peak rate over the period to 2050 in ‘stretch’ scenario of the LULUCF GHG inventory projections.</p>

Limitations

239. UKTM has a number of limitations:

- The model only takes account of a subset of the full costs and benefits of meeting a given carbon budget level. In addition, only technical factors are taken into account in the roll out choices (costs, maximum build rates etc.).

⁷² Industrial energy use from a bottom-up perspective: developing the usable energy database, 2013, Griffin et al https://data.ukedc.rl.ac.uk/simplebrowse/edc/efficiency/industry/EnergyConsumption/UED_Documentation.pdf

Behavioural or other practical considerations that might make certain pathways undesirable or difficult to achieve are not accounted for. In addition, the modelled solution will delay roll out of the more expensive options required for as long as is technically possible, given the assumed maximum deployment rate and overarching emissions constraint. This result is due to the discounting of future costs and because costs are then incurred for a shorter time period, as the modelling ends in 2060.

- The results for each run of the model take no account of risk or uncertainty. The pathways modelled by UKTM are therefore only least-cost and achievable if all of the underpinning assumptions turn out to be correct over the whole period. It is unlikely in practice that all technologies would achieve the costs and performance assumed and that the availability and maximum build rate assumptions could all be achieved. This aspect also contributes to the model delaying the roll out of more expensive options, as it does not factor in the risk that some of these options may not be fully viable, and the impact this could have on achieving the UK's 2050 emissions target.
- The level of detail in UKTM varies across different sectors and, as with any model, is a simplified representation of the real world. Because it does not fully reflect the diversity in technology options and user choices it may understate the diversity of technologies that could contribute to achieving meeting targets at least-cost. UKTM does not include behavioural measures, such as transport modal shifts or increased household recycling.
- Sectors where the majority of emissions are not related to energy use, such as agriculture, are modelled in less detail in UKTM than in sector-specific models. Other sectors are generally more granular in UKTM in terms of the number of technology options but less detailed in terms of the factors that affect variation in costs. For instance, UKTM takes no account of variation in heat network costs due to geospatial factors, instead applying an average cost per unit of capacity. Competition for use of land, including diverting it from other uses such as agriculture, is also likely to be an issue in the higher biomass availability scenarios but these interactions are not taken into account within UKTM. It is important to note that UKTM does not price risk, or directly factor in uncertainty. Therefore, each solution that UKTM finds is dependent on every assumption about each technology (e.g., cost, maximum build rate, maximum availability) coming true. UKTM effectively states the latest decision points to start mitigation actions, in a deterministic world under perfect foresight.

Sector representation and technology coverage

240. Each of the sectors has a variety of technical abatement opportunities at different costs. No behavioural measures are captured. Key model assumptions include efficiencies, availability dates, lifetimes, resource availability and cost, capital costs, operational and maintenance costs, and the potential savings through installing measures. These are drawn from the best evidence available at the time of analysis. Details of some of the key assumptions and sector representations are below.
241. For the purposes of reporting UKTM emission outputs the following sector categories are used. These emissions categories are not necessarily fully aligned with forthcoming sector strategies.

Table A3: UKTIMES sector definitions

Domestic transport	Emissions from all road transport modes, associated with rail travel, domestic aviation and shipping.
Industry	Emissions from manufacturing and construction, including cement, chemicals, food & drink, iron & steel production and non-energy use.
Fuel supply	Emissions associated with non-electricity fuels supply including upstream oil and gas production, refineries and hydrogen production emissions.
Buildings	Emissions from domestic (residential) and non-domestic (business and public) buildings.
Electricity	Emissions associated with electricity supply including operating energy from waste plants.
Agriculture	Emissions associated with agricultural activities.
Waste	Emissions associated with waste management.
F-gases	Emissions from Fluorinated-gases.
LULUCF ⁷³	Emissions from land use sources and sinks, including wetlands emissions.
Engineered removals	Emissions removals from engineered technologies (BECCS and DACCS).
Int'l Aviation & Shipping	Emissions from international aviation and shipping.

⁷³ Figures in brackets indicate adjustment for Tier 2 peat emissions in line with the accounting scope of this Impact Assessment.

A.3 GLOCAF model and fair-share pathway methodology

242. Analysis of effort sharing of global emissions reductions has been conducted using BEIS Global Carbon Finance model – GLOCAF. The model allows the user to evaluate the impacts of different global emission reduction targets, burden sharing regimes, as well as various specifications of the carbon market design. It covers the years 2025, 2030, 2035, 2040 and 2050.
243. GLOCAF is a scenario modelling tool based on Business As Usual (BAU) emissions and Marginal Abatement Cost (MAC) curves for different regions and sectors providing global economy-wide coverage.
244. GLOCAF uses data from:
- The POLES energy model: this is a partial equilibrium energy model, which takes into account the costs of different technologies as well as the potential demand feedback effects within the energy system.
 - IIASA's G4M and GLOBIOM models for forestry and non-CO₂ agriculture emissions; these are partial equilibrium models of the forest sector, incorporating the opportunity costs of abatement from forestry.
245. All datasets are at a sector level and apply to a number of regions. GLOCAF models 25 world regions and 24 sectors although a different level of disaggregation is possible if the data supports it.
246. At the heart of GLOCAF is a model of global carbon markets. It compares the supply of carbon abatement or International Carbon Units (driven largely by MAC curves) to the demand for mitigation, (determined by the difference between BAU and regional targets). The model finds the market clearing carbon price where the demand for carbon permits matches their supply for each market. This is done through an iterative process around the carbon price. These curves are constrained by trade restrictions around, for example, supplementarily (the requirement for a certain part of a target to be met domestically) and/or participation.
247. GLOCAF uses the market clearing carbon price to determine how much abatement each region and sector carries out, and the associated incremental cost. Using the carbon price and associated trading of carbon permits GLOCAF also determines the resulting international financial flows.
248. There are a number of limitations of GLOCAF modelling:
- GLOCAF only models specific years, and as such GLOCAF results focus on 2035 rather than the whole sixth carbon budget period;
 - GLOCAF marginal abatement cost curves only include direct costs of mitigation and exclude wider impacts such as co-benefits of mitigation or avoided costs of emissions;
 - Although GLOCAF models most major emitters individually, it aggregates many smaller emitters into regions, meaning that effort share calculations were done at regional rather than country level in many cases;
 - GLOCAF assumes that countries will always choose least-cost mitigation options. This may not always happen in practice.
249. These limitations mean that GLOCAF results should always be considered to be illustrative rather than as forecast of real-world outcomes.

250. GLOCAF data includes BAU projections which are calibrated to the International Energy Agency's World Energy Outlook 2019 Current Policies Scenario.

Table A4: Summary of effort share approach assumptions

Effort share approach	Assumptions
Global Emissions Budget	Uses the IPCC global pathways to calculate an implied global emissions budget 1990-2050 consistent with a given warming scenario. Allocates total budgets to countries on the basis of cumulative population and calculates the amount remaining per country between 2020-2050, applying this linearly over the period.
Weighted Emissions Budget	Uses the IPCC emissions budgets to calculate global emissions 1990-2050 consistent with a given warming scenario. Allocates total budgets to countries on the basis of cumulative population and calculates the amount remaining per country between 2020-2050, applying this linearly over the period. However, historical emissions in more recent years are weighted more than those from more distant years.
Contraction and Convergence	The 2035 convergence point is calculated by dividing the global emission target by projected population in 2035. Each country is given a 2035 target based on the convergence point multiplied by their projected population.
Equal cost	Under this approach all country targets are set so that all countries face the same net abatement costs as percentage of GDP. Mitigation costs per capita are proportional to GDP per capita, making this approach equivalent to a flat tax. An iterative process is used within the GLOCAF model to adjust each country's target up or down until its mitigation cost is within an acceptable tolerance of the global average and the required global emission target is met.
Capability	The 'Capability' approach allocates emissions in 2035 to countries in a way which reflects both their GDP per capita and their level of population: other things equal, countries with comparatively low GDP per capita and comparatively high populations receive larger shares of emissions allocations than richer, smaller countries.
Minimum global cost	The GLOCAF model is used to calculate the amount of abatement each country would deliver for a given carbon price, such that the marginal cost of mitigation is the same across all countries.

A.4 Supplementary evidence base

251. This annex provides more details on supplementary evidence that was used to inform the assessment criteria.

Supplementary cost and benefits

252. Due to limitations of the UKTM model, some supplementary calculations have been made to the cost benefit analysis to rectify these where possible. See table A5 for a list of off-model adjustments.

Table A5: Summary of off-model adjustments to UKTIMES for appraisal

Sector	Cost type	UKTM limitation	Adjustment source
Power	Cost	Insufficient coverage of power sector cost types, particularly balancing, interconnector and distribution network costs.	BEIS Dynamic Dispatch Model and Distributions Network Model
Power	Cost	Adjustment for share of energy from waste policies included in modelling	BEIS Dynamic Dispatch Model
Waste	Cost	Waste costs are not included	Defra's waste policy appraisal modelling
Shipping	Cost	Capex and opex costs of shipping not included	Modelling commissioned by DfT ⁷⁴
Shipping	Air quality	Overestimate of air quality benefits relating to international shipping	Modelling commissioned by DfT.
Agriculture	Air quality	Air quality impacts of anaerobic digestion not included	Defra anaerobic digestion model
Agriculture and Land use	Natural capital	Non air quality natural capital impacts not covered by UKTM.	Defra's agricultural and forestry policy appraisal modelling

253. With respect to the air quality benefits for shipping, due to significant differences between the baseline year air pollutant emissions estimated by the modelling commissioned by DfT and the methodology used in the UK's National Atmospheric Emissions Inventory⁷⁵, it is expected that the air quality benefits for shipping are still overestimated, though by significantly less than if UKTM was used.

⁷⁴ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/816018/scenario-analysis-take-up-of-emissions-reduction-options-impacts-on-emissions-costs.pdf

⁷⁵ See Section 7.3.1 of https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/816019/scenario-analysis-take-up-of-emissions-reduction-options-impacts-on-emissions-costs-technical-annexes.pdf for further details.

Power sector

254. The DDM model, a comprehensive model of the electricity system, was used to inform UKTM's power assumptions. This model was also used for the prices and bills analysis to inform a projection of electricity prices over the next 15 years.
255. The DDM is an electricity supply model, currently modelling the GB power sector out to 2050. It allows analysis of the impact of different policy decisions on capacity, costs, prices, security of supply and carbon emissions. The DDM employs two key algorithms:
- Dispatch algorithm, which models electricity supply and demand.
 - Investment algorithm, which forecasts revenues and costs based on Dispatch algorithm for new plants and retirements.
256. The DDM relies on many exogenous assumptions and inputs, and results can be sensitive to changes in these assumptions. Key assumptions include generation and financing costs, build limits, security of supply requirements, electricity demand (for the purposes of this modelling aligned with UK demand derived from UKTM).
257. The DDM has several limitations, the most important of which are:
- It is deterministic, in that a given set of inputs will always produce the same outputs.
 - Plants are assumed to be profit maximising, and act according to economic rationality.
 - The DDM does not tell us the optimal mix of technologies to ensure security of supply or decarbonise. The mix is defined by user inputs (for the purposes of this analysis these have been informed by the Modelling 2050: electricity system analysis paper⁷⁶ that was published with the Energy White paper).
258. The Average Prices and Bills Model (APBM) uses outputs from models across government, including the DDM, to provide estimates of the impact of government policies on energy prices and bills for different consumers. It covers both electricity and gas for domestic and non-domestic consumers.
259. The APBM relies on exogenous assumptions and inputs, and can be sensitive to changes in these assumptions. Key ones include electricity demand (for the purposes of this modelling aligned with UK demand derived from UKTM), average consumer demand and policy/funding decisions.

⁷⁶ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/943714/Modelling-2050-Electricity-System-Analysis.pdf

A.5 Natural capital

260. A more detailed breakdown of the natural capital impacts described in section 2.6 is provided here.

Quantified natural capital impacts

261. Some natural capital impacts have been taken into account in the cost benefit analysis and are included in the headline NPVs. Table A6 provides a breakdown of these. These values refer to analysis of the CCC sixth carbon budget level under the core pathway.

Table A6: Summary of quantified natural capital impacts

Natural capital pillar	Net present value	Positive contributing policies	Negative contributing policies
Air quality	£34.7bn	Shipping, reduced fuel combustion for power, transport and buildings, agricultural practice reform	Anaerobic digestion, increased industrial pollutants, biomass use
Water quality and quantity	£3.1bn	Agricultural soil improvement and peat restoration	
Biodiversity	£0.5bn	Afforestation	
Recreation	£0.9bn	Afforestation	
Flood management and landscape	£0.8bn	Afforestation and energy forestry	

Cross-cutting: Land-use trade-offs

262. Land is a finite resource. Predicting exactly how land use will change in order to meet future demands for food, energy, resources, housing, recreation, biodiversity, waste, nature and emissions abatement, is challenging even where policy levers are established. Meeting the sixth carbon budget will require significant and competing demands from land, resulting in large changes to its use and management.

263. Such levels of land use change could impact how we produce our food, urban developments and nature, with knock-on effects for other land use types and agriculture. Land use will be under pressure for conversion to lower carbon land uses and management regimes. For example, there are competing demands for different types of natural carbon dioxide removal technologies such as tree planting, biomass or peatland restoration. This will involve trade-offs between different grades of land, conversion to other uses, and environmental values such as biodiversity and landscapes, in order to meet population needs and targets.

Recreation and amenity

264. Achieving the sixth carbon budget could have positive impacts for recreation and amenity, with a transition to a low carbon economy providing spaces to enjoy nature as well as likely increasing tree planting for bioremediation and forestry more widely (where access permitted), peatland restoration and green transport. Demand for land use change may have negative impacts on access to green space, recreation and amenity

value, and therefore mitigating actions and trade-offs should be considered when determining the suite of policies for reaching the sixth carbon budget. For example, large industrial plants associated with GGRs, solar and wind could impact visual, amenity value and add to noise pollution.

Air Quality

265. The Government is subject to legally binding air pollutants emissions ceiling obligations (i.e., the National Emission Ceilings Regulations, 2018)⁷⁷. Overall, achieving the sixth carbon budget will reduce emissions of several air pollutants as climate change and air pollution are strongly related and have many of the same contributing emission sources. The sixth carbon budget will have impacts in areas such as transport, buildings (related to energy efficiency measures, heat pumps etc.), and switching from fossil fuel combustion to wind and solar power will significantly reduce emissions of NO_x, fine particulate matter (PM_{2.5}), NMVOCs and SO₂.
266. However, there is a significant risk over the lifetime of net zero policy delivery that the specific policies chosen could be detrimental to the Government's ceiling obligations, Clean Air Strategy, and 25 Year Plan targets commitments. There is a risk that the health of the public may also be negatively impacted, in some cases and in some areas. This is particularly the case for:
- Ammonia emission from the production of biogas and biomethane using anaerobic digestion. Reducing ammonia emissions is a priority because it is detrimental to ecosystems, reduces biodiversity and impacts peatlands' ability to store carbon; when in the atmosphere, it can deposit more nitrogen onto soils, plants and freshwaters than they can cope with, as well as impacting human health by contributing to the formation of fine particulate matter. It will also result in significant irreversible biodiversity declines in particular ecosystems. Therefore, mitigating technology to reduce emissions is necessary, at any level of the sixth carbon budget that relies on anaerobic digestion plants, in order to meet the UK's legally binding ammonia reduction target for 2030. Mitigation technology will also help achieve CC targets, as well as biodiversity targets set out in the 25 Year Environment Plan and the Leader's Pledge for Nature.
 - Biomass for electricity production and for heating. There is a risk of increased emissions of NO_x and PM_{2.5} from unabated biomass combustion.
267. These risks have been included in the cost benefit analysis in section 2.6.
268. Ongoing consideration of the potential impacts of air pollutants at a local scale is needed. While overall emissions reductions is an overall indicator of progress in air quality, it is not an effective indicator in reducing the impacts of pollution which are influenced by the local concentrations of pollution in closer proximity to sensitive ecosystems or centres of population. Although modelling suggests that in the main, with the exceptions cited above, air pollutant emissions will be lower at a national scale, it is possible that place-based hotspots of ammonia, particulates or the secondary pollutant ozone could be inadvertently generated. If more localised concentration increases of these pollutants occurs, this will result in unintended human health, ecosystem, and therefore economic impacts.

⁷⁷ <https://www.legislation.gov.uk/ukxi/2018/129/contents/made>

Water Quality and Quantity

269. Whilst many policies reduce water demand, some low carbon technologies are water-intensive and large-scale implementation could mean unsustainable demand. For example, nuclear power, CCS and hydrogen production require high levels of water input for cooling and electrolysis respectively. Further, although land management and some productivity options are likely to have positive impacts on water quality by reducing nutrient leaching and sedimentation through reduced soil erosion, overall intensification of agricultural production is likely to create additional water quality and usage pressures, including for the marine environment. Furthermore, the impact, in many cases local, of the proposed afforestation/biomass planting rates on water resources/availability needs to be noted, given the higher water use of trees, particularly fast-growing and productive woodland, over other land covers. Additionally, innovative options such as Anaerobic Digestion can have negative impacts on water quality if not handled carefully, particularly through the increase of nutrients on the overall available land bank.
270. This is set against a backdrop of increasing global water scarcity in a changing climate. Therefore, water demand both regionally and nationally should be considered at a systems level when considering the suite of policy options to meet the sixth carbon budget, to ensure sustainable demand. Alongside this, the suite of policies chosen to reach the sixth carbon budget may have positive and negative impacts on water quality, and these should be assessed on a case-by-case basis and mitigating actions taken where necessary.

Biodiversity – terrestrial and marine

271. In the long-term, the level of the sixth carbon budget can be positive for biodiversity (marine and terrestrial), including habitat restoration, connectivity, resilience and reducing ecological stress caused by climate change. However, biodiversity and habitats are spatially and climatically explicit, meaning locations and extent of future policies may have negative impacts, including displacement, noise pollution and habitat loss. Mitigating actions and trade-offs should be considered when determining the suite of policies for reaching the sixth carbon budget, including for low carbon technologies, GGRs, marine policies, land management and agricultural intensification.
272. The Dasgupta review⁷⁸ highlights that our economies, livelihoods and well-being all depend on nature and, in particular, biodiversity. Engaging with nature sustainably starts with understanding and accepting a simple truth: our economies are embedded within nature, not external to it. The review provides a comprehensive review on the economics of biodiversity and sets a precedent for government analysis on incorporating all natural capital impacts.

Raw Materials, Resource Efficiency and Waste

273. Materials are finite. Some low carbon technologies are dependent on critical raw materials, many of which are rare, found in unique locations and in high demand globally. There are risks associated with overreliance on specific technologies where raw material scarcity may grow and geopolitics may determine access, for example, rare earth elements such as neodymium for use in magnets.
274. Resource extraction and processing have significant negative impacts on natural capital assets. Natural resource use is currently heavily correlated with consumption demands. Therefore, where pathways to meet the sixth carbon budget include policies to improve

⁷⁸ The Economics of Biodiversity: The Dasgupta Review, 2021, <https://www.gov.uk/government/publications/final-report-the-economics-of-biodiversity-the-dasgupta-review>

resource efficiency (to prevent waste) and increase recycling rates, it could have the dual positive impact of decreasing embodied natural capital costs and carbon emissions in products and reducing those associated with waste management. Further, policies which keep critical raw materials in circulation for longer could alleviate pressure for more extensive mining.

275. As biodegradable waste is diverted from landfill and use of AD increases, an increased amount of digestate will be generated. This should be rigorously assessed to establish its value for soil improvement and potential impacts on waterways.

A.6 Accounting for Devolved Administrations' views and characteristics

276. The Climate Change Act requires consideration of the “differences in circumstances between England, Wales, Scotland, and Northern Ireland”. Collectively Scotland, Wales, and Northern Ireland accounted for 22% of UK emissions in 2018.⁷⁹
277. The Climate Change Act sets a long-term target to reduce emissions of GHG emissions by 100% in 2050 relative to 1990. Each of the Devolved Administrations are committed to the UK net zero commitment in the Climate Change Act, but the level of ambition through the carbon budgets and individual targets set by the nations can vary.

Scottish Government view

278. Scotland introduced its own legislative framework through the Climate Change (Scotland) Act 2009 and has an interim target to reduce emissions by 75% by 2030 relative to 1990 (including IAS). The Act also requires the Scottish Government to set annual emission targets from 2010-2050 and requires reducing GHG emissions by 3% each year from 2020.
279. The Scottish government considers the CCC's recommendation (Option 3) the “minimum level of ambition” at which the budget should be set, in order to support the action needed in reserved areas to meet statutory emissions reduction targets set by the Scottish Parliament. It also supports the CCC position on carbon accounting, notably the inclusion of IAS emissions, in line with the approach already taken in Scotland. Furthermore, it is of the view that the fifth carbon budget should be reset in law to align with the CCC's recommended pathway to net zero in 2050, and the NDC level in 2030.

Welsh Government view

280. Wales has [laid regulations with a view to update] its own statutory emissions reduction pathway this year, including to adopt a new net zero target for 2050. Its interim targets include a 63% and 89% reduction in GHG emissions by 2030 and 2040 respectively, compared to 1990 levels. Wales also has a target to reduce GHG emissions by 3% each year from 2011, relative to a baseline of average emissions over 2006-2010.
281. The Welsh Government view is that the UK's sixth carbon budget should be set at the level recommended by the CCC (Option 3), considering it an important part of being consistent with Wales's proposed new targets and carbon budgets, while noting the influence the UK can have internationally as it hosts COP26.
282. Wales supports the CCC position on carbon accounting, most notably the inclusion of IAS emissions, in line with the approach already taken in Wales. It is also of the view that the fifth carbon budget should be reset in law to align with the CCC's recommended pathway to net zero in 2050, and the NDC level in 2030.

Northern Ireland view

283. Northern Ireland has a target to reduce GHG emissions by 35% (from 1990 levels) by 2025. It is considering advice from CCC on what would be considered Northern Ireland's fair and equitable contribution to achieving UK net zero, which will guide the development of future climate change legislation.
284. Northern Ireland is supportive of the CCC's recommendation on the level of the sixth carbon budget for the UK.

⁷⁹ Note: 1990-2019 UK GHG emissions published Feb 2021. Equivalent DA GHG emissions estimates due to be published June 2021.