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Treatment of uncertainty in determining the UK's path to Net Zero

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The Climate Change Committee (CCC) recommended the UK's 2050 Net Zero target in 2019 and then the emissions pathway to this as part of its advice on the Sixth Carbon Budget at the end of 2020. As part of this, the CCC's analysis included development of five pathways to Net Zero, incorporating a number of judgements and framings regarding uncertainty and decision points, to highlight key choices for Government and wider society on the path to Net Zero. This paper explores how the analysis, and its presentation, framed these choices and uncertainties, in order to highlight where decisions are required and what the trade-offs and potential contingency options might be. It concludes with reflections on the effectiveness of this approach and on the future challenges on decision-making and uncertainty toward Net Zero.

KEYWORDS

Net Zero, carbon budget, deep decarbonization, uncertainty, climate legislation

1 Introduction

The Climate Change Committee (CCC) is the statutory advisor to the UK Government on climate change, as set out under the (Climate Change Act, 2008). Part of the CCC's role is to recommend the level of each five-year carbon budget (i.e., the limit on greenhouse gas emissions over the specified five-year period) on the path to the long-term emissions goal for 2050, which are recommended around 12 years before the commencement of the carbon budget period.

In 2020, the CCC recommended the level of the Sixth Carbon Budget (CB6), which sets the limit on emissions over the period 2033–37. This was the first time a carbon budget had been set on the path to the 2050 emissions goal of "Net Zero," which was recommended by the CCC in May 2019 and placed in legislation in June 2019.

A key question for the consideration of uncertainty on the path to Net Zero is how this can be considered, while ultimately recommending a single number to be placed in legislation for the level of allowed emissions over a five-year carbon budget period, 12 years hence.

The path for emissions on the 30-year path from 2020 to Net Zero in 2050 is uncertain in a range of ways [e.g., see the papers in the rest of this Special Issue, including Workman et al. (2023)]. This paper sets out the ways in which the analysis and framing for the CB6 advice treated this uncertainty. The advice itself (Climate Change Committee, 2020a) and the accompanying Methodology Report (Climate Change Committee, 2020b) set out more detail in many areas, while the CCC's recent Briefing on Determining a pathway to Net Zero (Climate Change Committee, 2023) provides a higher-level overview.

2 The challenge of addressing uncertainty in the Sixth Carbon Budget Advice

The underlying requirement of the December 2020 advice on the level of CB6 was to advise on the level of the carbon budget for the period 2033–37, accompanied by a range of accompanying recommendations (e.g., on treatment of emissions from international aviation and shipping in the carbon budget). The Government is then required to legislate a level for the carbon budget, either in line with the CCC's advice, or – if different – setting out why the level differs from that recommended by the CCC.

This legislative requirement for the carbon budget level does not allow explicitly for uncertainty – however uncertain the path to 2050 is considered, the Climate Change Act requires a single number for the limit on emissions for the five-year period to be placed in law. This means that all treatment of uncertainty must ultimately be focused on justifying why the recommended level of the carbon budget is robust to the uncertainties considered. The only aspect of the Climate Change Act that allows for uncertainty is an allowance, subject to the advice of the CCC, to revise the level of a carbon budget should there be a significant change in circumstances. To date, this avenue has not been pursued.

Following the legislation of a carbon budget, the Government is required to set out its plan for meeting the carbon budget on the path to 2050, including policies and proposals to achieve it. Just as the CCC advice on the level of the carbon budget should consider uncertainty in the emissions path, so should the Government's strategy, including contingency options to ensure the legally-binding carbon budget.

Moving from setting carbon budgets on the path to a 2050 goal for an 80% reduction in greenhouse gas emissions to a 2050 Net Zero goal inherently reduces flexibility in the pattern of emissions in 2050:

- The Net Zero goal is considerably more stretching, leaving very little room for emissions above the "de minimis" level in each sector of the economy, such that the overall residual level of emissions is sufficiently small to be balanced by greenhouse gas removals.
- Conversely, the 80% target allowed for considerable residual emissions to remain overall. This provided some inherent flexibility, as it was possible to allocate these significant allowed residual emissions to sectors in different ways (e.g., different optimisation modeling exercises allocated substantial residual emissions to the buildings sector or to the transport sector).

The choice over the emissions picture in 2050 is therefore collapsed down to the extent to which residual emissions above a "de minimis" level are allowed and balanced with additional greenhouse gas removals. However, the assessed scope for this is limited, given the estimated limits to deployment of greenhouse gas removal technologies by 2050.

3 Scenario approach to the Sixth Carbon Budget Advice

Following on from the Net Zero advice, part of the CCC's approach to CB6 was to acknowledge that this degree of freedom for 2050 had been eliminated but to highlight the remaining degrees of freedom. This entailed setting out a sufficiently broad "solution space" for 2050, highlighting the remaining choices and flexibilities in achieving Net Zero (i.e., the choices between different technologies and the role of behavior change).

The CCC's 2019 advice on Net Zero had been deliberately cautious in its assumptions, for example on future technology costs and the degree of societal and behavioral change, in order to act as a "proof of concept":

- While some behavioral and societal changes were included, such as a 20% reduction red meat and dairy consumption and a limiting of aviation demand growth to 25% on 2018 levels rather than the 70% considered to represent "business as usual" the assumptions used were deliberately not pushing at the boundaries of what might be achievable. In part, this was due to lack of evidence on the degree of such changes that could actually be achieved in practice.
- Limiting the changes to "moderate" levels enabled the advice to be framed as showing that Net Zero could be achieved even based largely on existing societal dynamics and deploying technologies that are already available or close to being so (e.g., continued widespread car use, but switching the car fleet entirely electric vehicles), albeit at a transformative scale within each sector, which helped with political acceptance and therefore the legislation of the Net Zero goal. While this is unlikely to represent the "best" way to achieve Net Zero, with greater societal changes bringing greater co-benefits, lower costs and less reliance on technologies such as carbon capture and storage, this framing could help gain political acceptance.
- It also had the effect to highlight the lengths that might be necessary to achieve Net Zero, such as the scale of greenhouse gas removals (GGR) and the overall costs that would be entailed. The Further Ambition scenario, which got close to Net Zero, included cautious assumptions on behavioral change and cost reductions. This assessment of cost therefore effectively acted as an upper bound on the estimate of the costs of achieving Net Zero.

However, in taking this approach, the scenario work for Net Zero had a bias toward large infrastructure and away from rapid innovation and societal changes that could ensure that Net Zero has lower costs and greater co-benefits. After publication of this work, it became clear that the wider solution space for Net Zero needed to be mapped, to enable society to take a set of choices over how to reach Net Zero.

With the Net Zero target agreed and legislated, it was then possible to take a different approach to the CCC's advice on CB6. In doing so, the CCC was able to recognize that other solutions to achieve Net Zero are possible, and indeed are likely to be more desirable than the 2019 Net Zero scenario. A key part

of the analytical approach for the CB6 advice was therefore to highlight the uncertainties and choices around achieving Net Zero in the UK by 2050. By adopting multiple scenarios for Net Zero (and the pathway to this), this provided freedom to depart from cautious assumptions and highlight the implications of uncertain but positive developments on the path to 2050.

The CB6 analysis initially focused on four "exploratory" scenarios for pathways to achieve Net Zero in or before 2050. These were designed to reflect the implications of different assumptions on two important uncertain dimensions regarding the transition, as well as some key choices around how to decarbonise in particular sectors:

The Committee decided that the different scenarios should be framed primary around key uncertainties that are primarily exogenous, rather than being policy choices. While there were many uncertainties that could have been represented, it was important to keep the analysis and number of scenarios manageable and to be able to present clear messages from the analysis. After significant consideration regarding the key uncertainties for achieving Net Zero, the CCC settled on two key dimensions of uncertainty on which to focus the analysis:

- *Societal and behavioral change:* We explored scenarios in which people and businesses are willing to make greater changes to their behavior. This considered further reductions in demand for the most high-carbon activities (e.g., aviation, meat and dairy consumption) and increases the uptake of some climate mitigation measures. While behavioral contributions has already been included in the Net Zero analysis, the extent of the potential in this area is uncertain. Including this dimension enabled the exploration of bolder assumptions in this area than could be justified based on current evidence.
- *Innovation and cost reduction:* We also looked at pathways in which there is greater success in reducing costs of low-carbon technologies, especially renewable electricity generation, and more extensive innovation in adopting new ways of doing things. Again, while some cost reductions had been factored into the Net Zero analysis, these were relatively modest. Including bolder assumptions enabled different ways of decarbonising, enabling more widespread electrification, a more resource- and energy-efficient economy, and more cost-effective technologies to remove CO_2 from the atmosphere.

In both cases, while assumptions had been made that assumed some contributions from societal and behavioral change and from innovation, these were deliberately included at conservative levels. This was partly due to a lack of evidence on the extent of these changes that could be possible in practice, but also partly due to framing decisions. Exploring these dimensions allowed the benefits of greater contributions in these areas, in terms of reduced costs of the transition and enhanced co-benefits, to be highlighted.

While these uncertainties that can, at least to a significant degree, be regarded as "exogenous" (i.e., not fully within the direct control of Government policy), this is not absolutely the case. Government policy can affect the extent to which the population might make low-carbon choices in future, as well as the effectiveness of innovation in bringing forward new solutions and cost reductions. Nevertheless, some societal changes will and should not be subject to control via policy, while much of the innovation that affects UK decarbonisation will be driven at the global, rather than national, level.

In addition to these two dimensions, the analysis did also fold in some different choices on how to decarbonise particular sectors. These built on prior CCC analyses on decarbonising UK buildings, hydrogen, land use, the role of biomass and greenhouse gas removals.

The analysis therefore explored the uncertainties over the degrees of innovation and societal/behavioral change by using a two-by-two matrix for scenarios. In both cases, the conservative end of the range corresponded to the assumptions made for the 2019 "proof of concept" Net Zero scenario, which still entail significant changes, but are considered to be at the conservative end of what may be turn out to be achievable. The other end of the range was more optimistic (i.e., it made Net Zero easier and/or less costly to achieve).

The Headwinds scenario, which assumes less optimism on each of these dimensions therefore broadly corresponds to the CCC's scenario from the 2019 advice. The other three scenarios were more optimistic in one or both of the two dimensions (Figure 1), framed as "high" change (i.e., the significant change assumed in 2019) and "further" change for these scenarios.

Into these scenarios were folded judgements on technology choices, broadly in line with the wider themes of these scenarios:

- *Widespread engagement* assumed higher levels of societal and behavioral changes. People and businesses are willing to make more changes to their behavior. This reduces demand for the most high-carbon activities and increases the uptake of some climate mitigation measures including those that require adjustment to different characteristics (e.g., heat pumps). There is an assumed preference for land-based greenhouse gas removals, and these are enabled by dietary changes that free up land for carbon sequestration (alongside reducing agricultural emissions). Assumptions on cost reductions were similar to those in Headwinds.
- *Widespread innovation* assumed greater success in reducing costs of low-carbon technologies. This allows more widespread electrification, a more resource- and energy-efficient economy, and more cost-effective technologies to remove CO_2 from the atmosphere. Assumed societal/behavioral changes were similar to those in Headwinds.
- *The Tailwinds scenario* is optimistic in both dimensions. While highly unlikely to be deliverable in full, given how stretching its ambition and uncertain its underpinnings, it represents the assessed likely limit of feasible economy-wide decarbonisation.

These four scenarios essentially represent the CCC's assessment of the feasible solution space for pathways to Net Zero in the UK in or before 2050, covering both uncertainties and choices on the path to Net Zero. As the scenarios were not artificially constrained to get to Net Zero in precisely 2050, some scenarios

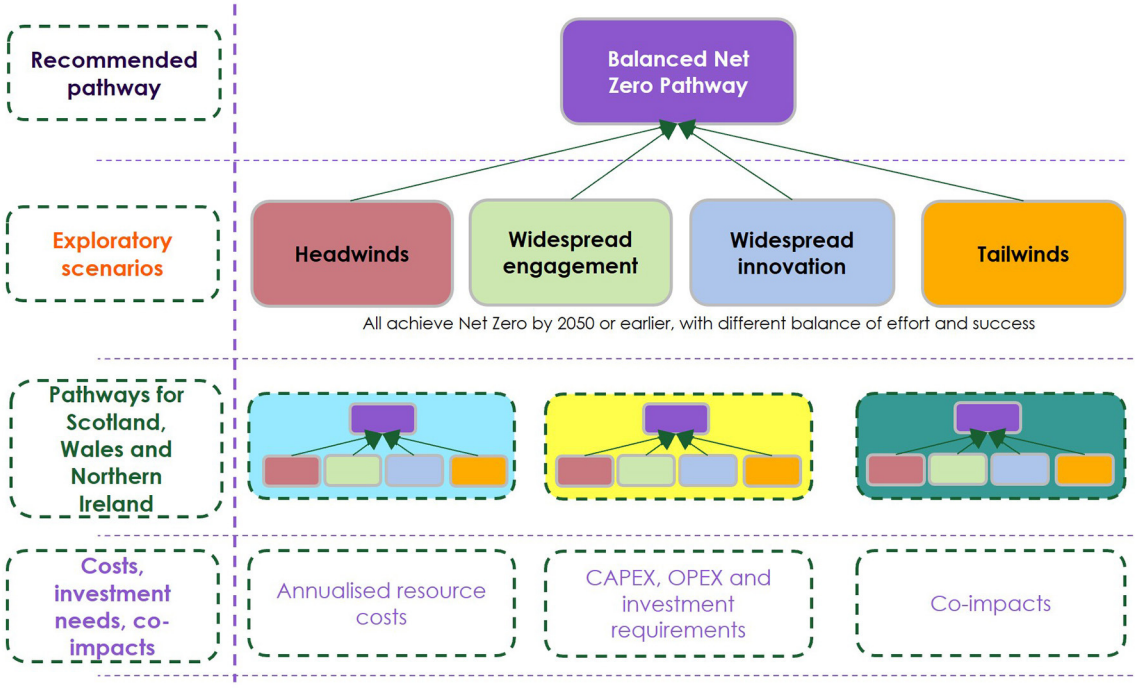

FIGURE 1
Scenario framework for the CCC's Sixth Carbon Budget analysis.

achieve this earlier, with Tailwinds getting there in 2042 (Figure 2). The scenarios intentionally do not cover a very wide set of potential outcomes under which Net Zero by 2050 is not achieved, though clearly given the set of challenges in achieving this it is important to acknowledge that the analysis deliberately focuses on a subset of the most favorable outcomes for UK emissions. We were also careful to highlight commonalities across all reasonable pathways to Net Zero, to limit the potential for uncertainty over the "correct" path to have a paralyzing effect on policy action.

The analytical approach for developing the scenarios was similar in each case, with common assumptions that rule out most forms of capital scrappage (e.g., premature retirement of fossil fuel boilers or cars). This means that all four pathways have relative smooth emissions trajectories, though at different rates of reduction (Figure 2). Measures to reduce emissions that had estimated costs well beyond the cost-effectiveness threshold used were also ruled out, unless justified by societal co-benefits, although more measures were cost-effective in those scenarios with greater assumed levels of innovation.

All four scenarios share many common features such as full decarbonisation of electricity generation and cars by 2050. However, the different assumptions affect both the level and pattern of emissions in 2050 and on the path to it:

- By 2050, the impacts of lower demands primarily affect emissions in two sectors: aviation and agriculture – these are the two sectors where activity at the margin still has a high carbon-intensity, so reducing demand makes a significant difference to emissions. Lower demands in other sectors (e.g., for car travel) affect emissions during the transition to Net Zero but this effect reduces toward 2050 as the carbon-intensity of the activity falls (e.g., as the car stock becomes all-electric), although there remain important considerations around indirect emissions impacts (e.g., in the production of cars) and there will often be non-climate reasons to have lower demand (e.g., congestion and air quality). The rapidity with which demand-side solutions can act means that cumulative emissions tend to be lower in the scenarios that assume lower demand.
- A key feature of the greater optimism on innovation is that lower costs of renewable generation enable decarbonisation via less-efficient uses of this generation (e.g., green hydrogen production, direct air capture of CO_2, synthetic aviation fuel production). In turn this enables lower emissions in aviation (via synthetic fuels) and less use of carbon capture and storage (CCS) for hydrogen production (from fossil gas) and bioenergy with CCS (BECCS) (Figure 3).

It is clear in the CCC's analysis that greater contributions from innovation and from behavioral and societal changes improve the outcomes of the Net Zero transition compared to the 2019 "proof of concept" scenario. However, uncertainty remains over the precise level of feasible on delivering many aspects of the transition, and it is unclear whether the solutions set out in the Widespread Innovation or Widespread Engagement pathways would be deliverable in full – this will become clearer over time, particularly as policy attempts to unlock some of these contributions.

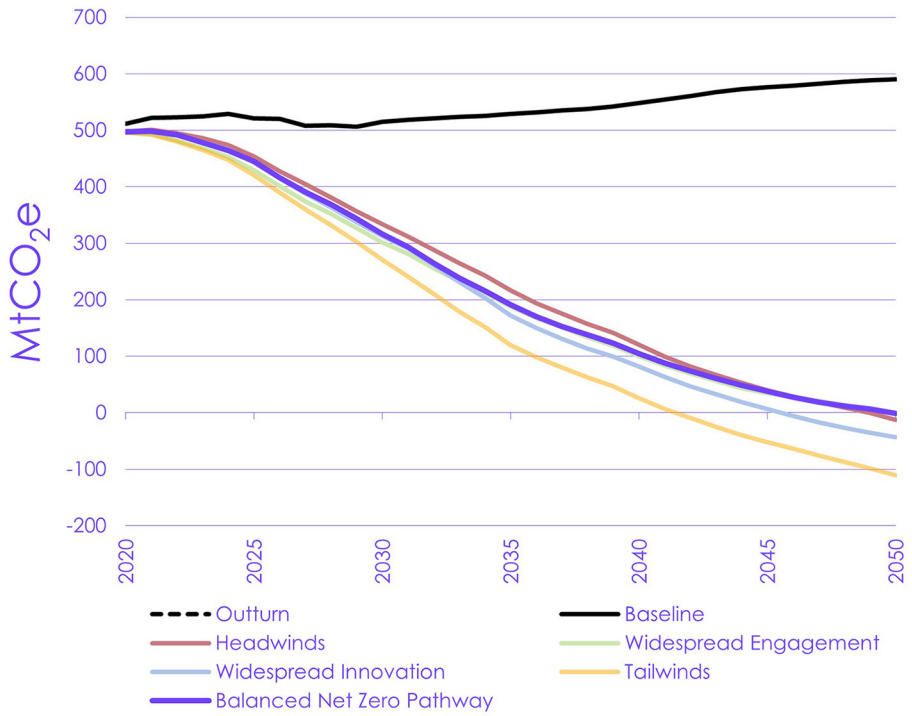

FIGURE 2
Emissions under the Balanced Pathway and exploratory scenarios.

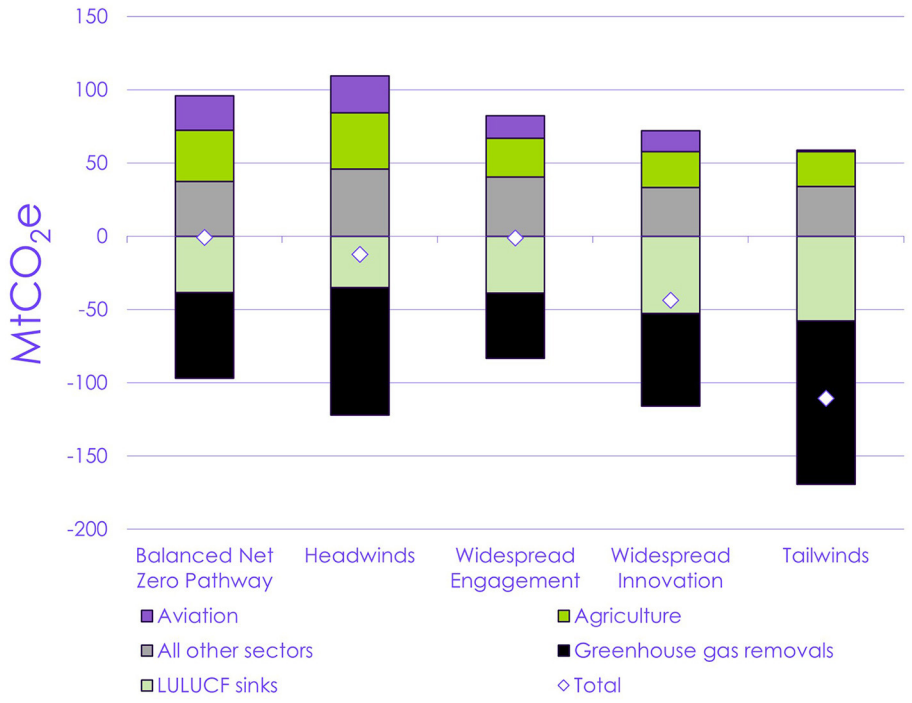

FIGURE 3
Residual emissions and greenhouse gas removals under the scenarios.

4 Bringing things together: the balanced Net Zero Pathway

Having assessed the solution space for the path to Net Zero in the four exploratory scenarios, a fifth pathway was constructed to represent the CCC's recommended path to Net Zero and underpin the advice on the level of the carbon budget. This Balanced Net Zero Pathway:

- Represented the Committee's view of a sensible strategy to underpin policy over the coming years, based on known technologies and behaviors.
- Minimized use of greenhouse gas removals (GGR), with feasible emissions reduction preferred to leaving residual emissions and balancing them with extra GGR.
- Embraced a wide set of solutions to contribute to Net Zero, limiting the delivery risks in any particular area and implying policy action across a wide range of areas, enabling the level of action to be ramped up further in future if feasible and necessary.
- Took a whole-system approach to decarbonisation, reflecting the range of opportunities across behavior, efficiency, land, low-carbon energy supply and end-use technologies, and how these potentially interact.
- Was designed to allow time for societal choices to contribute and the necessary scale-up of supply chains, skills, business models and infrastructure during the 2020s and aimed to develop key options for decarbonisation in the 2030s and 2040s through action in the 2020s.
- Included some measures that are not cost-effective when considering only emissions reductions, where they support other objectives (e.g., some higher-cost improvements to energy efficiency of homes, due to benefits to fuel poverty, health and employment).
- Aligned very well to the preferences expressed by the Climate Assembly UK (2019), which was called by six Select Committees of the House of Commons to understand public views on how the UK should tackle climate change.
- Was designed to put the UK on track to Net Zero, and supports the required global path for decarbonisation by reflecting the highest possible ambition on emissions reduction as a necessary contribution the Paris Agreement.

The Balanced Pathway therefore represented the Committee's assessment of the most sensible set of actions to reduce emissions over the path to Net Zero by 2050, given the available information at the time. However, even with this assessment, uncertainties remain over how this translates into emissions during the mid-2030s, on the path to Net Zero by 2050, for example the level of economic activity across the economy, which will affect "baseline" emissions (i.e., the level without the set of actions to reduce emissions).

5 Justifying the level of the recommended Sixth Carbon Budget

While the scenario approach addressed two key dimensions of uncertainty on the path to Net Zero, these do not represent the full extent of the uncertainties or the CCC's analysis for the advice on the level of CB6.

The set of actions in the Balanced Pathway was translated into a trajectory for emissions using a range of models and macroeconomic assumptions (e.g., population, economic growth, energy demand, fossil fuel prices), generally based on the best available "central" projections from Government and public bodies. The Sixth Carbon Budget Methodology Report (Climate Change Committee, 2020a) sets out in detail how this was done.

Future decisions will also be made on scientific methodologies to estimate emissions and on conventions on how emissions are allocated between countries. We identified the potential emissions implications of different choices, and then took the choice to err on the side of assuming the future choice that would lead to a higher estimates of emissions and therefore for a higher level for the carbon budget. In this way, a known future decision on emissions accounting could not cause the set of actions in the Balanced Pathway to be insufficient to meet the legislated carbon budget.

In setting a legal limit on emissions, it is clearly important to understand how different out-turn in these areas could affect the achievability of the carbon budget. The Committee considered that balanced consideration of uncertainties and risks was both important within the analytical process and also an inherent part of the presentation of the advice.

The CB6 advice presented an assessment of a considerable range of uncertainties, in terms of their potential impacts on emissions during the CB6 period, relative to those in the Balanced Pathway. As well as assumptions on macroeconomic factors and on future emissions accounting methodologies and conventions, the advice also considered the impact of delays in Government in implementing climate policy and the opportunity for buying extra emissions reductions via additional biomass imports to enable the UK to implement greenhouse gas removals at a larger scale by 2035 (Figure 4).

While the analysis, conducted during 2019 and 2020, was unable to incorporate assumptions on the long-term effects of the COVID-19 pandemic on behavior at a sectoral level, an indicative possible economy-wide impact was presented based on an additional assumed 6% reduction in emissions in 2035. Again, by including this effect only as a sensitivity, the carbon budget recommendation was robust to a "V-shaped" recovery in the economy post-pandemic that did not have a lasting effect on demand and emissions across the economy.

In this way, we were able to demonstrate that the recommended limit on emissions for the Sixth Carbon Budget period, based on the actions in the Balanced Pathway, is achievable under a range of different assumptions and that opportunities exist for extra action to meet the carbon budget should macroeconomic factors push baseline emissions higher than projected.

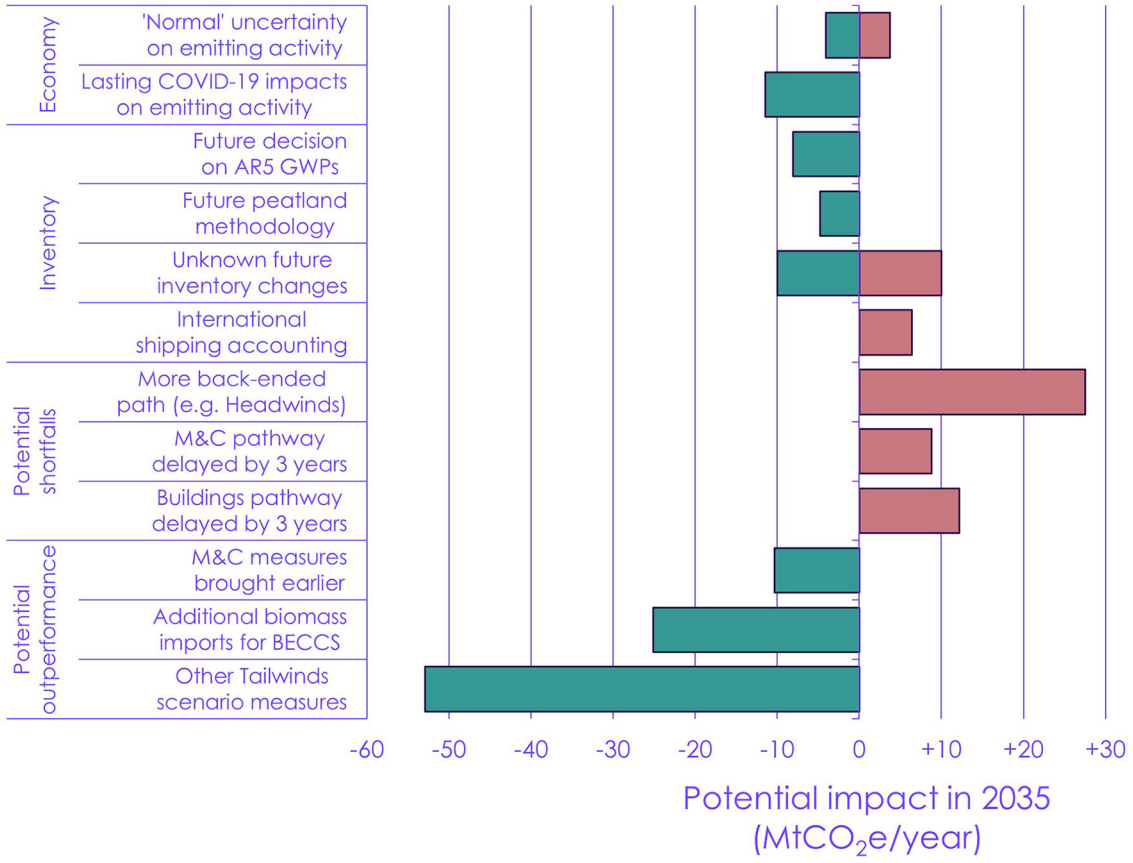

FIGURE 4
Risks and opportunities for emissions to differ from the Balanced Pathway in 2035.

6 Lessons for the future

Since the advice on the Sixth Carbon Budget was provided (and the carbon budget was legislated at the level recommended), circumstances have shifted significantly. Russia's invasion of Ukraine sent prices of fossil fuels, especially gas, to very high levels. This has prompted some policy responses from the UK Government. If this very high level of fossil fuel prices had been anticipated in the CCC's analysis, the Balanced Pathway would likely have been affected in several ways:

- *Baseline demand/emissions:* Higher energy prices generally mean lower demand, regardless of policy efforts to tackle climate change. This will tend to mean that for a given level of policy effort, emissions will be lower than assumed with more moderate fossil fuel prices.
- *Pace of low-carbon technology roll-out:* The improved economics of non-fossil technologies can be expected to lead to more rapid uptake. For example, data for December 2022 indicate that plug-in vehicles accounted for 40% of UK car sales, ahead of even the Tailwinds pathway.
- *Choices between low-carbon technologies:* Higher fossil fuel prices typically make moving to low-carbon technologies (e.g., electric vehicles, renewable electricity) cheaper. However, the balance between non-fossil technologies and those that use fossil fuels with carbon capture and storage (CCS) will tend to shift toward the former at higher fossil fuel prices. This is exemplified by the Government's greater ambition for renewables and nuclear capacity in its Energy Security Strategy, which implicitly is likely to leave less space for gas plants with CCS.

While the CCC's sectoral analysis did include sensitivity analysis, this did not come close to covering a situation in which fossil fuel prices spiked to such a degree:

- The sectoral analysis for the pathway development did include sensitivity analysis to fossil fuel prices, which was directionally as expected. However, in many cases it was assumed that much faster uptake in response to higher fossil fuel prices would not be feasible, given constraints on other important issues such as supply chain capacity and infrastructure development.
- Conversely, slower developments in response to lower fossil fuel prices was generally considered inappropriate, due to the deployment challenges that anyway exist in relation to reaching Net Zero by 2050.
- As such, uncertainty in fossil fuel prices was reflected in two main ways in the advice:

- The economy-wide consideration of costs looked at the macro-level implications of different fossil fuel prices to the overall costs of meeting the Sixth Carbon Budget and Net Zero. Again, this was directionally as expected, and produced a range for the net cost of achieving Net Zero via the Balanced Pathway of around 0.5% of GDP across the range of BEIS fossil fuel prices.
- The scenarios with greater optimism on innovation (i.e., Widespread Innovation and Tailwinds) explored cases with relatively low costs of decarbonisation relative to prevailing fossil fuel prices. Although this was due to an assumption of low-carbon technologies getting cheaper rather than fossil fuels getting more expensive, many of the dynamics are similar.

Given the very high fossil fuel prices following Russia's invasion of Ukraine, the Tailwinds scenario – which pairs low abatement costs with a focus also on demand reduction – has many of the features that would be expected in a scenario with very high fossil fuel prices, at least for the energy sectors.

It is worth reflecting that had the pathway for the Sixth Carbon Budget taken more account of fossil fuel price uncertainty, this would not necessarily have been in the direction that would appear appropriate in hindsight (i.e., of considering higher fossil fuel prices).

- During the analytical process in March 2020, COVID lockdowns came into effect in the UK and elsewhere and fossil fuel prices fell precipitously. As this was partway through the analysis process for developing sectoral pathways, extra sensitivity analysis was added to identify the impact of very low oil and gas prices.
- Therefore had greater emphasis been placed on this, it could have led to lesser decarbonisation ambition due to the extremely low prevailing fossil fuel prices during 2020. It was not widely considered, inside the CCC or outside, that within 2 years the UK wholesale gas prices would rocket to record levels.

7 Reflections for future advice

It is crucial to account for uncertainty in recommending a carbon budget. The process of doing so, as set out here, seems likely in general to lead to a recommendation somewhere toward the middle of the pathways being considered.

The value of stretch pathways such as Tailwinds is therefore only partly to sketch a future in which things go as hoped and Net Zero can be achieved by the early 2040s. Their other role is to highlight specific areas in which it is possible to go further than a "central" scenario, to counterbalance concerns over potential shortfalls in some areas. This both (a) provides a menu of options to compensate for under-performing the central emissions pathway in some areas (e.g., due to policy failures and/or wider reasons such as economic growth being higher than projected) and (b) underscores that the Balanced Pathway is not an extreme scenario in which every policy lever is used to its maximum extent and every policy perfectly designed.

It is therefore instructive to consider what would be required in order to recommend a carbon budget that goes even beyond the ambition of the Balanced Pathway and the legislated Sixth Carbon Budget. To set in law something closer to the Tailwinds pathway would require options to be identified that could counterbalance the sizeable risks of falling short of that highly ambitious path in some areas. This could include:

- Identifying ways to go even further in emissions reductions, for example due to new technological developments
- Examination of "emergency" options to reduce emissions that can be enacted quickly to counter emerging shortfalls in abatement at short notice, including:
  - Strong, rapid demand-side action (e.g., sharply reducing the numbers of allowed flights to and from UK airports)
  - Premature scrappage of capital equipment (e.g., fossil fuel boilers, cars)
  - Additional importation of low-carbon hydrogen and sustainable biomass, should the energy system be able to accommodate their extra use.

Given the work done already in the Sixth Carbon Budget advice to set out different choices for Net Zero by 2050, it is unclear how valuable it would be to repeat a similar process. An alternative could be to develop fewer full pathways, with more sensitivity analysis on areas of uncertainty. This approach would make it possible to demonstrate the range of emissions in a pathway originating from various sources of uncertainty. In order to ensure that the carbon budgets are robust against these uncertainties, different approaches are possible:

- The development of a timeline setting out decision points for contingency plans should it become clear that a carbon budget, or the Net Zero target, are at risk due to the realization of an uncertain assumption implying higher future emissions than projected.
- For uncertainties that can be short-term in nature, or where contingency plans would take too long to mitigate the risk, the pathway could use the conservative side of the uncertainty range for a given assumption, rather than the central value.
- For uncertainties regarded to be outside the direct control of Government policy, for example significant changes in greenhouse gas accounting methodologies, it is possible to use the allowance within the Climate Change Act, that the level of a carbon budget can be revised should there be a significant change in circumstances.
- Consideration of uncertainties outside the treatment of the models used, for example the assumption that industrial structure and output remains broadly as it is today.

The input of the Climate Assembly process into the CCC's scenario development ensured that the assumptions made were considered broadly acceptable. However, societal preferences can and will change over time. Further deliberative approaches will be valuable in understanding changes over time in what society considers feasible and desirable, so that the approach to decarbonisation can adjust to this.

Although the framing of the evidence-based conclusions of the advice as relatively moderate (e.g., in comparison to the Tailwinds pathway) has value in making it seem achievable, and therefore more politically palatable, there is a risk that the scale of the endeavor required to meet the Sixth Carbon Budget and Net Zero are underplayed. While the CCC's advice set out in considerable detail the nature and scale of the changes entailed in the Balanced Pathway, it is easy for those who want the political reward for committing to ambitious targets to gloss over the challenges in delivering the changes required to meet them. It is notable that the Parliamentary debate on legislating the Sixth Carbon Budget only took 17 min, which suggests that some politicians may not yet grasp the scale of the Net Zero endeavor.

The Sixth Carbon Budget advice presents a highly ambitious decarbonisation pathway to 2050 commensurate with the challenge presented by the UK's legislated Net Zero target. By design, the majority (63%) of the emissions reduction from 2020 to 2050 occurs in the first half of the period. This is appropriate, both to minimize cumulative greenhouse gas emissions and to ensure that sufficient progress is made so that what remains to achieve in the 2040s is largely comprised of the remaining emissions reductions in the most difficult areas and scaling up greenhouse gas removals to balance those emissions that cannot be eliminated.

The UK now has a comprehensive target framework for emissions reduction. What matters now is action, with a focus on delivery and on developing and implementing remedial action where progress is off-track. No matter how high the quality of the advice provided by the CCC, it is merely an advisor to the Government, which must decide on its decarbonisation strategy and ensure that it is delivered.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

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