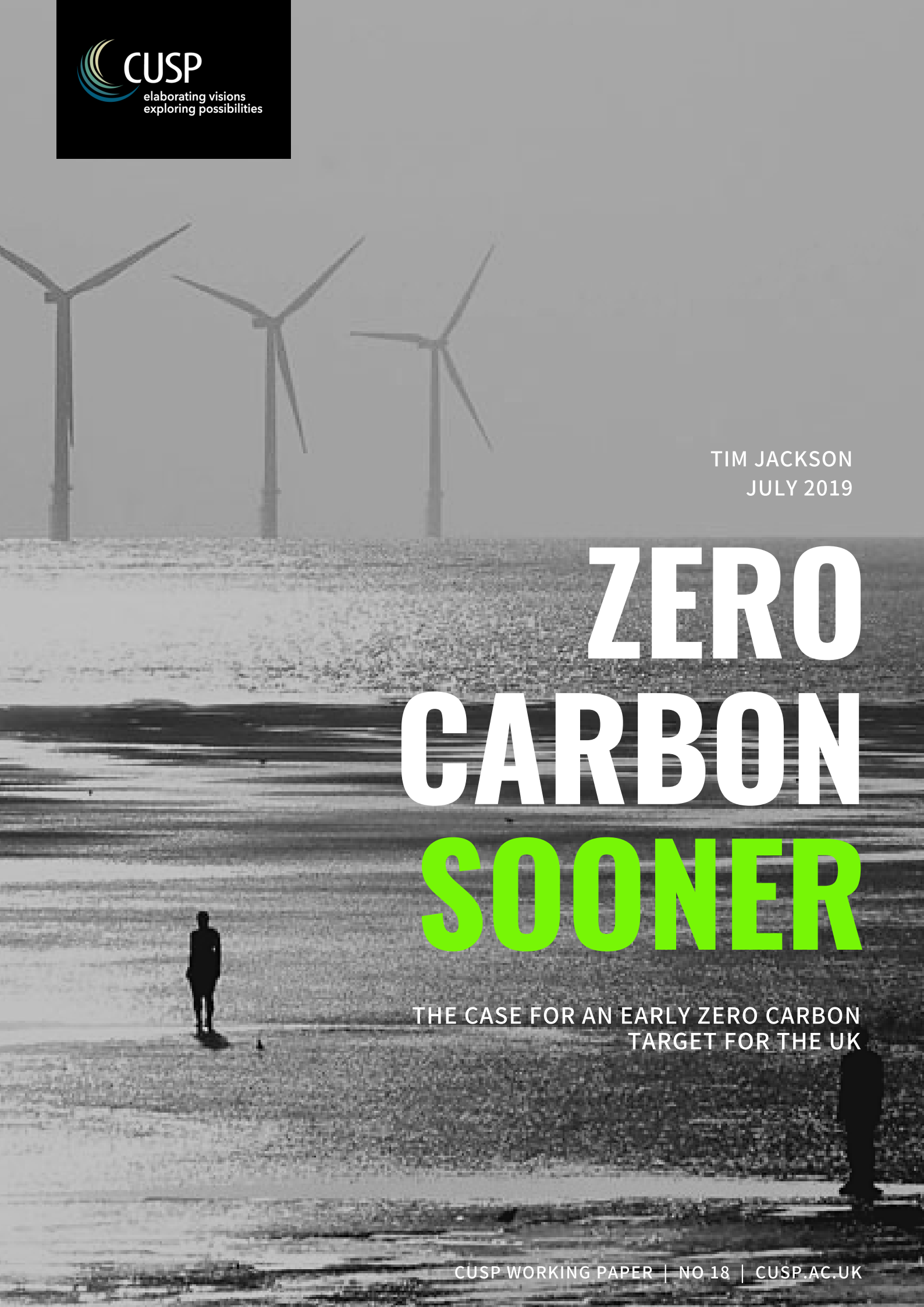
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Abstract

This briefing paper addresses the question of when the UK should aim for zero (or net zero) carbon emissions. Starting from the global carbon budget which would allow the world an estimated 66% chance of limiting climate warming to 1.5° C, the paper derives a carbon budget for the UK of 2.5 $GtCO_2$. The briefing then analyses a variety of emission pathways and target dates in terms of their adequacy for remaining within this budget. A key finding is that a target date for zero carbon is not sufficient to determine whether the UK remains within its carbon budget. Policy must specify both a target date and an emissions pathway. For a linear reduction pathway not to exceed the carbon budget the target year would have to be 2025. Nonlinear pathways, such as those with constant percentage reduction rates, have a higher chance of remaining within the available budget provided that the reduction starts early enough and the reduction rate is high enough. It is notable that reduction rates high enough both to lead to zero carbon (on a consumption basis) by 2050 and to remain within the carbon budget require absolute reductions of more than 95% of carbon emissions as early as 2030. On this basis, the paper argues in favour of setting a UK target for net zero carbon emissions by 2030 or earlier, with a maximum of 5% emissions addressed through negative emission technologies.

Introduction

Climate science agrees that even a 1.5° C warming above pre-industrial levels carries significant risks for ecosystems and for human society. But it is a better target than 2° C warming which would amplify all of those risks substantially.[1] The UK Climate Change Commission's recent report on net zero recommended that the government should strengthen its current target of 80% reduction in greenhouse gas (carbon) emissions by 2050 to a 'net zero' target for the same date.[2]

This working paper sets out the case that the UK should aim for a zero carbon target considerably sooner than 2050. It is worth noting that other countries have already adopted earlier dates. Sweden has a net zero target for 2045, Finland for 2035 and Norway for 2030—the most ambitious of any government.[3] Extinction Rebellion has called for the UK to eliminate all carbon emissions by 2025.[4]

The Global Carbon Budget

The starting point for consideration of a zero-carbon target is the global 'carbon budget'. This is the amount of carbon that can be emitted into the atmosphere from now until the end of this century, usually measured in terms of tonnes of carbon dioxide (CO_2).[5] The most recent IPCC estimate of available global carbon budget (from the end of 2017) that would give us a 66% chance of remaining within the 1.5° C warming target is 420 $GtCO_2$ (billion tonnes of CO_2).[6] This budget is being depleted by current emissions of 42 Gt CO_2 per annum.[7] If emissions were to stay at this level, the global carbon budget will be exhausted by the beginning of 2028. For the last two years, global carbon emissions have been rising.[8] If they continue to rise the budget will be exhausted sooner than 2028.

A Fair Carbon Budget for the UK

The question of an appropriate carbon budget for the UK depends on both arithmetical assumptions and the ethical position taken in relation to the UK's historical responsibility and the rights of the poorest countries in the world to develop their economies and allow their citizens a decent quality of life.

If we were simply to divide the available global carbon budget and allocate it on an equal per capita basis, assuming that the global population stabilises at around 10 billion people in 2050, and the UK population stabilises at 70 million (say) at around the same time, then the UK's share of the global carbon budget would be approximately 2.9 $GtCO_2$.

Given the UK's historical responsibility for carbon in the atmosphere and the undeniable need for development in the poorest countries in the world, there is a very strong argument that the UK should adopt a carbon budget which is lower than this. So, for example, if each person in the poorest half of the world were to have an allowable carbon budget 33% higher than each person in the richest part of the world on a per capita basis, this would lead to a 'fair carbon budget' for the UK of around 2.5 $GtCO_2$. This remains a relatively conservative assumption perhaps in relation to the UK's moral responsibilities and there may well be an argument for allowing an even higher carbon budget for the poorest countries.[9] But under this assumption, 2.5 $GtCO_2$ is all the carbon that the UK could fairly emit between 2018 and the end of the century.

How long can the UK budget last?

There is no simple answer to this question, because it depends how fast we cut our carbon emissions over time. If we cut emissions faster, we can afford a later target. If we cut too slowly, the budget will be exhausted and we will be faced with the task of installing uncertain and costly 'negative emission technologies'[10] to take carbon out of the atmosphere (and potentially the oceans) for the rest of the century.

The time to exhaustion of the budget also depends on the basis on which we account for UK emissions—whether on a production basis, counting only the territorial emissions generated on UK soil, or on a consumption basis, counting the emissions associated with UK consumption patterns including those from aviation and those embedded in trade with the rest of the world. The position taken in this paper is that the consumption perspective is the correct one when viewed from an ethical perspective. But in either case, we can get some sense of how long the budget will last by making different assumptions about the rate of emissions reduction (on these different bases).

Production basis

The level of carbon emissions in the UK, as measured on a production basis, was 364 $MtCO_2$ in 2018.[11] If emissions continued at this level, the UK's budget would be exhausted by 2025. As it happens, production-based emissions have been falling since 2010 at a rate of around 4% per year. But even if they continued to fall at the same rate, the carbon budget would be exhausted only one year later in 2026 (Figure 1(a)). By 2050, emission levels would still be almost 100 $MtCO_2$ per year, leading to a 'carbon overdraft'[12] of more than 4 $GtCO_2$.

Suppose instead that we aim to reduce carbon emissions year on year, along a linear path that would ensure zero carbon emissions by 2050. The path is designed to reach the current UK target for net zero on a production basis. But we would nevertheless exceed the carbon budget at more or less the same time as for the trend pathway (Figure 1(b)). By 2050 the carbon overdraft would still be almost 3.5 $GtCO_2$. In fact, the latest year that we could afford to reach zero carbon emissions on a production basis along a linear pathway, without exceeding the carbon budget, would be 2030, in less than twelve years' time (Figure 1(c)).

It remains possible of course to try and extend the available budget by cutting emissions faster than the linear trend. Suppose, for example, that instead of following a linear path, we were to cut emissions by around 15%

year on year over the next three decades. Under this assumption (Figure 1(d)), emissions in 2050 would be just over 2 $MtCO_2$ per year, and there would still remain around 87 $MtCO_2$ in the carbon budget. At a reduction rate of 14%, however, only slightly lower than this, the budget would have been exhausted by 2040 and we would need to use 'negative emissions technologies' to remain at net zero carbon until the end of the century.

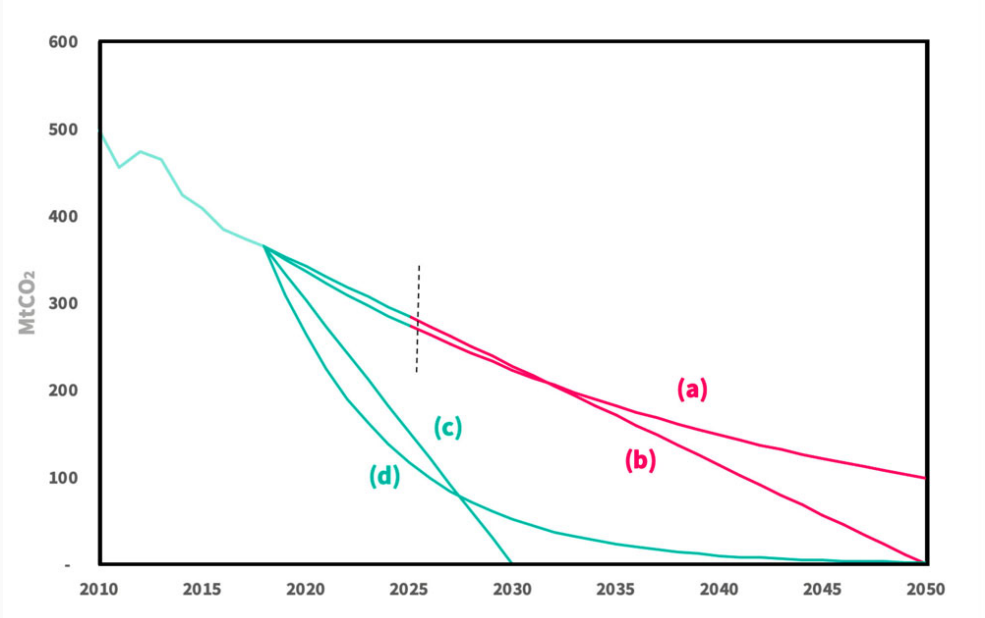

Figure 1: Historical emissions and future emission pathways (production perspective)
a) trend rate of reduction; b) zero carbon 2050 along a linear pathway c) zero carbon 2031 along a linear pathway; d) 15% annual rate of reduction. The dotted vertical line indicates the point at which the carbon budget is exhausted for pathways (a) and (b).

Consumption basis

Production-based emissions underestimate the carbon footprint of UK citizens by omitting some of the carbon associated with UK consumption patterns. The territorial (production) account omits international aviation emissions and the carbon embedded in imported goods and services, for example. There are strong moral arguments to suggest that the UK should adopt a target which reduces its 'consumption footprint' to zero (or net zero) rather than simply its territorial (production-based) emissions.[13]

Measured on a consumption basis, current emissions in 2016 were 660 $MtCO_2$—almost 60% higher than production-based emissions.[14] Emissions have also been falling on a consumption basis since 2010, although at a rate of only 1.5% per year, considerably slower than production-based emissions. Extrapolating this trend to 2018 suggests that the UK was responsible for

around 590 $MtCO_2$ on a consumption basis in 2018. If emissions continued to fall at this rate, the UK's carbon budget would be exhausted by 2023, in just four years' time, and emissions would still be in the region of 550 $MtCO_2$ (Figure 2(a)). Without a massive deployment of costly and uncertain negative emissions technologies, the 'carbon overdraft' in 2050 would be almost 13 $GtCO_2$.

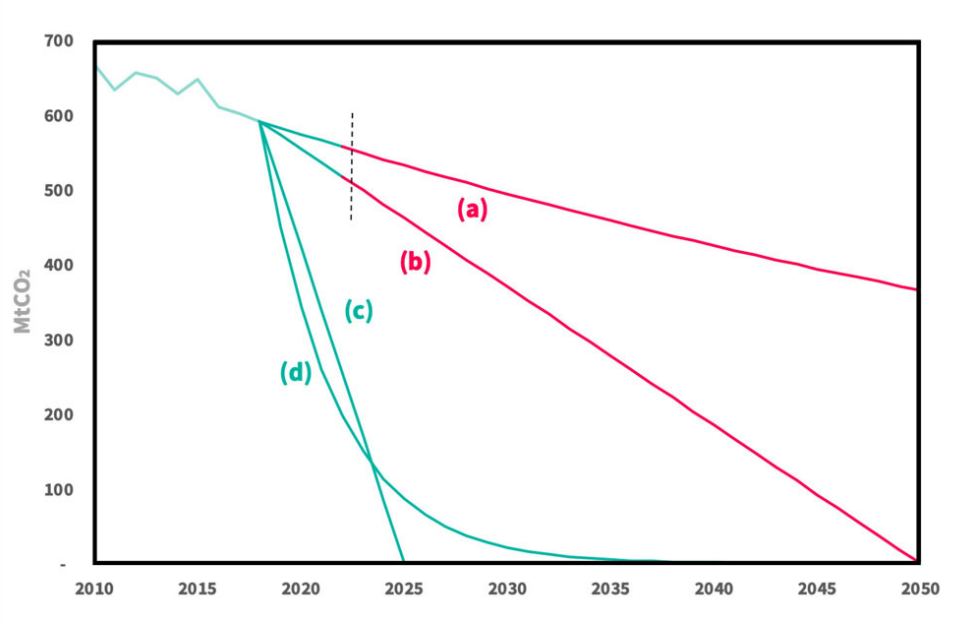

Figure 2: Historical emissions and future emission pathways (consumption perspective)
a) trend rate of reduction; b) zero carbon 2050 along a linear pathway c) zero carbon 2025 along a linear pathway; d) 24% annual rate of reduction. The dotted vertical line indicates the point at which the carbon budget is exhausted for pathways (a) and (b)

Suppose instead that we aim to reduce consumption-based emissions year on year, along a linear pathway that would lead to zero emissions by 2050. We would still be overdrawn on our carbon budget by 2023 (Figure 2(b)), at about the same time as for the trend pathway. The remaining level of emissions would be slightly lower than the trend case at just under 500 $MtCO_2$. But the carbon overdraft by 2050 would still be over 7 $GtCO_2$.

It turns out that the latest date at which we could aim for zero carbon along a linear pathway without exceeding the carbon budget would be the end of 2025 (Figure 2(c)). To achieve that target, the annual average reduction would need to be around 85 $MtCO_2$ per year. The remaining carbon budget in 2025 would be approximately 130 $MtCO_2$. Taking just one year longer to reach the target along a linear pathway would lead to a carbon overdraft of more than 160 $MtCO_2$.

Once again, it is possible to conceive of emissions pathways that lengthen the time to exhaustion of the carbon budget by exceeding the linear reduction rate in the early years. For example, a year on year reduction rate of around 24% (see Figure 2 (d)) would extend the UK's budget until 2050. What is interesting about such pathways is that even by 2030 residual emissions would only be 22 $MtCO_2$, less than 5% of consumption-based emissions today. This level of emissions may well lie within the range of feasible options for negative emissions technologies.[15]

What does this mean in terms of zero carbon targets?

The implications of this analysis for the UK are profound. The first and most important lesson is that the current UK target for net zero is, on its own, insufficient to guarantee that the country remains within its carbon budget. In fact, when measuring carbon emissions on a consumption basis, a net zero target of 2050 could lead to a 'carbon overdraft' more than five times the UK's 'fair carbon budget'.

Remaining within any budget depends inherently on the emissions pathway the country follows. Policy must therefore align any target date for zero carbon with a proposed emissions reduction pathway. It may also need to put in place a policy process that could re-align the target date if the actual emission pathway deviates from the target emissions pathway, since this will inevitably shift the timescale on which the budget is exhausted.

It is also worth pointing out that each year the target level of emissions reduction is not achieved, the task in subsequent years gets significantly harder. Missing even one year of the required reductions along the pathway would change all the calculations, leading to higher reduction requirements in subsequent years and making it substantially more difficult to stay within the carbon budget.

When it comes to identifying an appropriate target for the UK, this briefing paper has been led by several principles:

- that the UK should remain within a fair carbon budget, calculated *pro rata* on a per capita basis and allowing a margin for historical responsibility;
- that emissions should be measured on a consumption basis to include all those emissions for which UK citizens are responsible;
- that reliance on negative emission technologies should be used only as a 'last resort' and at a minimum level, consistent with evidence on their availability and effectiveness.

Under these assumptions, the analysis here has identified the year 2025 as a safe zero carbon target, along a linear pathway. This is the same year that Extinction Rebellion has called for the UK to achieve net zero emissions. To achieve this target along a linear pathway, the UK would have to start cutting carbon emissions immediately by around 85 $MtCO_2$ per year.

It is possible for the target date to be extended beyond 2025 *if only if* the rate of reduction of carbon emissions is faster than the linear pathway in the early years. In fact, the target date for zero carbon could even be extended to 2050, if the annual rate of carbon emissions reduction were in the region of 24% every year between now and then. This would be equivalent to a reduction of 140 $MtCO_2$ in the first year, with smaller reductions in subsequent years as the overall emissions level declined.

What is notable about such pathways is that within little more than a decade, carbon emissions must already have fallen to a very low level. For example, with a 24% rate of reduction, UK emissions will already have fallen to only 22 $MtCO_2$ by 2030 ((Figure 2(d)). This is less than 5% of the current level of emissions, measured on a consumption basis. Such a level of emissions could conceivably be offset by a careful programme of domestic negative emissions technologies, without imposing high and uncertain costs on future generations or on other countries.

There is nothing that can substitute for early 'deep' carbon reductions when it comes to making the task easier in the long run. In these circumstances, it makes no sense to set a target date of 2050. The most appropriate way to ensure that the UK remains within its fair carbon budget is to aim for an early net zero target of 2030 (say) with a defined maximum level of negative emission technologies. A later target (say 2035) could also be set, so long as the reduction rate was sufficient to ensure that the fair carbon budget is not exceeded, without excessive use of negative emission technologies.

It is clear that the reductions involved here are very substantial. The level implied by the linear pathway, namely 85 $MtCO_2$, has only been approached once since 1997, in the year 2009, when the carbon footprint fell by 80 $MtCO_2$ during the financial crisis. But that level of reduction has not been sustained in the years since. The best post-crisis reduction in the carbon footprint was in 2016 which saw a fall of 38 $MtCO_2$ over the previous year.[16] There has been no sustained period of year on year decline in the carbon footprint at anything like the level needed since 1990.[17] This illustrates an important point about achieving the reductions identified in this paper. When the economy is in a state of continual growth, efficiency

improvements are offset by an expansion in scale and the task of reducing carbon emissions is made considerably more difficult.[18]

Adopting a consumption-based approach poses an additional challenge in terms of the degree of control over the emissions embedded in UK trade. There do exist policy measures—border tariffs for example—which could affect these emissions, but control is clearly less immediate than in the case of domestic emissions. Adopting a production-based approach would eliminate this pressure and reduce the challenging nature of the percentage and absolute reductions needed. But it does not appropriately take account of the UK's carbon responsibilities.

Ultimately, the setting of a target date depends on the position a country takes in relation to its global responsibility and the speed with which it is prepared to take action to reduce emissions to net zero. Notwithstanding the challenges associated with achieving the carbon reductions identified here, the lessons from this analysis are clear. There is every indication that the current UK net zero target of 2050 is insufficient either to reflect our global responsibility or to motivate the early action that is needed if the carbon budget is not to be exhausted long before the target date.

In summary, the moral and prudential case for the UK to adopt a zero target sooner than 2050—perhaps as early as 2025 and no later than 2035—appears to be a very strong one.

Notes

1 IPCC 2018 SR15—Summary for policymakers. Online at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf

2 CCC 2019. Net zero—the UK's contribution to stopping global warming. Online at: https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/.

3 See: https://www.climatechangenews.com/2019/06/03/finland-carbon-neutral-2035-one-fastest-targets-ever-set/; http://www.climateaction.org/news/norway_brings_forward_carbon_neutral_target_to_2030.

4 https://rebellion.earth/the-truth/demands.

5 In looking at carbon emissions and the rate of decarbonisation this note only explores CO_2 emissions. This is consistent with the use of an overall budget denominated in terms of CO_2. But as IPCC SR15 makes clear, the CO_2 budget also depends on what happens to non-CO_2 greenhouse gases. This would need to be explored separately.

6 IPCC 2018 SR15—Summary for policymakers. Section C.1.3. Online at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf

7 IPCC 2018 SR15, C.1.3 (see note 1)

8 Jackson et al 2018. Global energy growth is outpacing decarbonization. Env Res Lett 13(12). Online at: https://iopscience.iop.org/article/10.1088/1748-9326/aaf303.

9 It is an open question whether such allowances could or should be 'tradeable' at the global level. This discussion has been part of negotiations within the Climate Change Convention from the beginning. But there is a strong moral case that aid to support less developed countries in reaching their own targets should be additional to developed country actions, not a substitute for it.

10 See for example: https://www.carbonbrief.org/guest-post-seven-key-things-to-know-about-negative-emissions; https://royalsociety.org/~/media/policy/projects/greenhouse-gas-removal/royal-society-greenhouse-gas-removal-report-2018.pdf.

11 BEIS 2018 Statistical Release. Online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/790626/2018-provisional-emissions-statistics-report.pdf. This excludes non-CO_2 emissions but it includes approximately 11 $MtCO_2$ of negative emissions from land-use and land-use change (LULUCF).

12 I use this term here to refer to an exceedance of the carbon budget. It is directly analogous to the concept of a bank overdraft, which arises when our spending exceeds the allowable funds—except that in the case of carbon the only 'banker' is future generations and the 'overdraft' is unauthorised.

13 https://www.theguardian.com/environment/2019/jul/14/climate-crisis-carbon-emissions-leakage-labour-party-corbyn.

14 See Defra 2017. UK's Carbon Footprint 1997—2016. Online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/794557/Consumption_emissions_April19.pdf. On a consumption basis, the UK's emissions in 2016 were around 600 $MtCO_2$ around 56% higher than production-based emissions of 384 $MtCO_2$ (BEIS 2018). Extrapolating that to 2018 leads to an estimate for consumption-based emissions in 2018 of 568 $MtCO_2$.

15 The Royal Society and the Royal Academy of Engineering report (note 10) includes a scenario which achieves 35 $MtCO_2$ from negative emissions technologies by 2050 for instance. Even including the current level of LULUCF (note 11), the scenario here would impose a lower need for negative emissions than the Royal Society scenario.

16 For the UK carbon footprint data series 1997 to 2016 see: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/794558/UK_Carbon_Footprint_1997_2016.ods

17 See Defra 2017 (note 14); for earlier years see Druckman A and Jackson T 2009 The Carbon Footprint of UK Households 1990-2004. *Ecological Economics* 68: 2066-2077. Online at: https://www.sciencedirect.com/science/article/pii/S092180090900366

18 See Jackson T 2017 *Prosperity without Growth*. (London: Routledge) Chapter 5. A simple illustrative model of this dynamic developed by Prof Peter Victor from York University in Canada can be found here: https://exchange.iseesystems.com/public/petervictor/emissions-reduction-model/index.html#page1; see also: https://exchange.iseesystems.com/public/petervictor/carbon-budget-simulator/index.html#page1