Building a zero-carbon economy – Call for Evidence

Background

On 15 October 2018 the governments of the UK, Scotland and Wales asked the Committee on Climate Change (CCC) to provide advice on the UK and Devolved Administrations' long-term targets for greenhouse gas emissions and the UK's transition to a net zero-carbon economy. Specifically: when the UK should reach net zero emissions of carbon dioxide and/or greenhouse gases as a contribution to global ambition under the Paris Agreement; if that target should be set now; the implications for emissions in 2050; how such reductions can be achieved; and the costs and benefits involved in comparison to existing targets.

The advice has been requested by the end of March 2019.

The UK's long-term emissions target is currently for at least an 80% reduction in greenhouse gas emissions from 1990 to 2050. It covers all sectors, including international aviation and shipping and is measured on a 'territorial' basis (i.e. based on emissions arising in the UK). On a comparable basis, emissions in 2017 were estimated to be 38% below 1990 levels.

The current target was set in 2008 based on advice from the Committee. That advice considered that to avoid the worst impacts of climate change, the central expectation of global temperature rise should be limited "to, or close to, 2°C", while the probability of crossing "the extreme danger threshold of 4°C" should be reduced to an extremely low level. That meant global emissions would roughly have to halve by 2050. The 2008 advice made the assumption that the UK should not plan to have a higher level of per capita emissions in 2050 than the global average.

The long-term target guides the setting of carbon budgets (sequential five-year caps on emissions that currently extend to 2032 and require a reduction in emissions of 57% from 1990 to 2030). Both the 2050 target and the carbon budgets guide the setting of policies to cut emissions across the economy (for example as set out most recently in the 2017 Clean Growth Strategy).

Any change to the long-term targets would therefore be expected to have significant implications, not just in the long-term but on current policies to drive the transition.

The CCC will advise based on a thorough consideration of the relevant evidence. We expect that to cover:

- The latest climate science, including as contained in the IPCC Special Report on 1.5°C.
- The terms of the Paris Agreement.
- Global pathways (including those reported by the IPCC) consistent with limiting global average temperature rise in line with the goals of the Paris Agreement.

- International circumstances, including existing plans and commitments to cut emissions in other countries, actions to deliver on those plans and opportunities for going further.
- An updated assessment of the current and potential options for deep emissions reductions in the UK and emissions removals from the atmosphere, including options for going beyond the current 80% target towards net zero.
- An appraisal of the costs, risks and opportunities from setting a tighter long-term target.
- The actions needed in the near term that would be consistent with achieving the long-term targets.

This Call for Evidence will contribute to that advice.

Responding to the Call for Evidence
We encourage responses that are brief and to the point (i.e. a maximum of 400 words per question, plus links to supporting evidence, answering only those questions where you have particular expertise), and may follow up for more detail where appropriate.

You do not need to answer all the questions, please answer only those questions where you have specific expertise and evidence to share. It would be useful if you could use the question and response form below and then e-mail your response to: communications@theccc.gsi.gov.uk using the subject line: 'Zero carbon economy – Call for evidence'. Alternatively, you can complete the question and answer form on the CCC website, available here.

If you would prefer to post your response, please send it to:

The Committee on Climate Change – Call for Evidence
7 Holbein Place
London
SW1W 8NR

The deadline for responses is 12 noon on Friday 7 December 2018.

Confidentiality and data protection
Responses will be published on our website after the response deadline, along with a list of names or organisations that responded to the Call for Evidence.

If you want information that you provide to be treated as confidential (and not automatically published) please say so clearly in writing when you send your response to the consultation. It would be helpful if you could explain to us why you regard the information you have provided as confidential. If we receive a request for disclosure of the information we will take full account of your explanation, but we cannot give an assurance that confidentiality can be maintained in all circumstances. An automatic confidentiality disclaimer generated by your IT system will not, of itself, be regarded by us as a confidentiality request.

All information provided in response to this consultation, including personal information, may be subject to publication or disclosure in accordance with the access to information legislation (primarily the Freedom of Information Act 2000, the Data Protection Act 1998 and the Environmental Information Regulations 2004).

Question and response form

When responding, please provide answers that are as specific and evidence-based as possible, providing data and references to the extent possible. Please limit your response to a maximum of 400 words per question.

Part 1: Climate Science

Question 1 (Climate Science): The IPCC's Fifth Assessment Report and the Special Report on 1.5°C will form an important part of the Committee's assessment of climate risks and global emissions pathways consistent with climate objectives. What further evidence should the Committee consider in this area?

ANSWER: Following the 1.5°C report, Professor Jason Lowe has noted that observational constraints tend to increase the carbon budgets, whilst analysis considering earth system approaches tend to reduce them. Moreover, some of those assessments that tend to increase the budgets appear to rely on maintaining a considerable aerosol load whilst simultaneously reducing fossil fuel use. In this regard the paper by Samset et al. points to the potential dangers of such an assumption https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017GL076079. The authors note how their modelling approach suggests that under 1.5°C of warming, removal of anthropogenic aerosols (principally sulphur) relates to an additional global surface warming of 0.5 to 1.1°C, with the land surface temperature rising by a further 0.7 to 1.6°C.

Similarly, other papers point to a risk of considerable emissions from soils as temperatures rise – further limiting the available carbon budget, for example: https://www.nature.com/articles/nature20150. Issues related to biological feedbacks give rise to considerable uncertainty, not just in terms of highly uncertain factors (e.g. levels, rates, types and timing of litter [leaf] fall) but then the actual implications of such factors on, for example, soil make-up & decomposition. Choosing how to internalise such compounded uncertainties needs to be considered in relation to the language of agreements etc.; it is not satisfactory to simply offer ranges to policy makers, but rather to link these to explicit translations and interpretations of the adjectival language that typically frame agreements (see the IPCC "guidance to authors"). As it stands, there are a range of potentially important feedbacks that are too poorly characterised to be included in the Earth System Models. The CCC should identify which feedbacks are included and excluded from GCM & ESMs and give a judgement on whether they would tend to increase or decrease the resulting carbon budgets.

Whether to favour scientific evidence that increases or decreases climate sensitivity (even when the evidence is of a similar quality) is not a neutral process and consequently assumptions need to be clear and justified. With regards to Paris and other international climate agreements, the language clearly errs more towards precaution than avoidable risk (e.g. "hold the increase in global average temperature to **well below 2°C"**. This needs to be considered if any subsequent advice offered (and based on science) is linked to such agreements. At present, there is the risk that analysis which offers a larger potential carbon budget tends to be more readily accepted than analysis that further constrains the space available, for a given temperature goal. Given how small even the most generous budgets are, there is a very high level of sensitivity of policy actions to budget size. A deeper appreciation of the risk of inaction, or ineffective mitigation policy in the short term, leaving emissions to continue to accumulate on an assumption that the budget for 2°C or 1.5°C is at the upper end of the range in the literature, is needed.

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Question 2 (CO_2 and GHGs): Carbon dioxide and other greenhouse gas gases have different effects and lifetimes in the atmosphere, which may become more important as emissions approach net-zero. In setting a net-zero target, how should the different gases be treated?

ANSWER: We advise caution in combining all well mixed GHGs in a net-zero target and suggest investigating a move away from the GWP100 approach.

Regarding methane, the dominant short lived climate forcer, Chapter 4 of Anderson & Broderick (2017) presents a review of choice of metric in relation to methane mitigation: https://www.research.manchester.ac.uk/portal/files/60994617/Natural_Gas_and_Climate_Change_Anderson_Broderick_FOR_DISTRIBUTION.pdf (pp. 20-34).

Notably, Allen et al (2016) identify that GTP40 for methane is aligned with the goals of the Paris Agreement (temperature based, appropriate timescale for 1.5 to 2 degrees stabilisation). This is a useful finding because it is numerically coincident with the widely used GWP100.

Consideration should be given to the GWP metric discussed further in Allen et al (2018) scenarios https://www.nature.com/articles/s41612-018-0026-8

However, its implications should be evaluated against higher RCP. This follows from our findings on i) the anticipated level of a non-CO_2 emissions floor from agriculture and ii) the strong potential for interaction with climate impacts in this sector. We caution that the 2°C RCP scenario, RCP3PD, has levels of N2O emissions that are lower than expected from a bottom-up consideration of the drivers of N2O (Bows-Larkin et al, 2014) https://www.tandfonline.com/doi/pdf/10.1080/17583004.2014.913859.

Part 2: International Action

Question 3 (Effort share): What evidence should be considered in assessing the UK's appropriate contribution to global temperature goals? Within this, how should this contribution reflect the UK's broader carbon footprint (i.e. 'consumption' emissions accounting, including emissions embodied in imports to the UK) alongside 'territorial' emissions arising in the UK?

ANSWER: This critical question requires a robust and defensible sequence of arguments from translating the language of Paris "well below 2°C" and "pursue … 1.5°C" into quantitative probabilities, through to determining the appropriate carbon budget range, and then apportioning this to nations on the basis of explicit and transparent sets of rules (with accompanying arguments explaining the reasoning and moral framework) taking as its starting point the first principle in the 1992 UNFCCC's –on "differentiated responsibility", principle.

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An appropriate approach is to start from the global budget range that is compliant with the Paris Agreement commitments and determine a set of rules that, if they were to be applied to other nations, would broadly be viewed as 'fair'. Importantly, the sum of all nations' budgets using this consistent approach must not exceed the global budget range. The CCC's Oct 2016 report [1] notes that a 1.5 degree budget would require net zero UK CO_2 emissions by 2045-2050 using the equity methodology underpinning its 2008 report (table 2.3), and notes that other equity approaches would lead to an earlier date (Box 2.3, figure 2.1). The 2008 approach is hard to align with the UNFCCC's differentiated responsibility criteria, as it only leads to equal per capita emissions in 2050, by which point there would be no carbon budget left. The CCC should consider the recent work of du Pont [2] against the UNFCCC principles in assessing an equitable contribution for the UK.

In addition, Tyndall Manchester researchers have used such equity approaches to develop carbon budgets for the EU, Scotland, Sweden, Greater Manchester Combined Authority, Manchester City Council and various Swedish municipalities (Kommuner) and regions (Län).

The EU version contains the method for transposing Paris global to EU carbon budgets [3]. The Scottish [4] and Manchester [5] & [6] reports disaggregate the budget still further, and include an approach for considering non-CO_2 emissions, CO_2 from LULUCF and a method for including aviation and shipping at a national (UK) level rather than disaggregating them to regions.

[1] https://www.theccc.org.uk/wp-content/uploads/2016/10/UK-climate-action-following-the-Paris-Agreement-Committee-on-Climate-Change-October-2016.pdf

[2] Du Pont, Y.R., Jeffery, M.L., Gütschow, J., Rogelj, J., Christoff, P. and Meinshausen, M., 2017. Equitable mitigation to achieve the Paris Agreement goals. *Nature Climate Change*, *7*(1), p.38.

[3]https://www.research.manchester.ac.uk/portal/files/60994617/Natural_Gas_and_Climate_Change_Anderson_Broderick_FOR_DISTRIBUTION.pdf (pp.7-19).

[4] https://www.research.manchester.ac.uk/portal/files/82366490/Quantifying_Scotland_s_Carbon_Budgets_for_Paris.pdf

[[5]http://www.mace.manchester.ac.uk/media/eps/schoolofmechanicalaerospaceandcivilengineering/research/centres/tyndall/pdf/Tyndall-Quantifying-Paris-for-Manchester-Report-FINAL-PUBLISHED.pdf)

[6] http://www.manchesterclimate.com/news/2018/10/playing-our-full-part-zero-carbon-2038-proposal

NB: Whilst we focus here on a production based accounting and budget setting, in line with the Paris Commitments, it is imperative that, as a minimum, we track our consumption emissions to assess our net decarbonisation performance.

Question 4 (International collaboration): Beyond setting and meeting its own targets, how can the UK best support efforts to cut emissions elsewhere in the world through international collaboration (e.g. emissions trading schemes and other initiatives with partner countries, technology transfer, capacity building, climate finance)? What efforts are effective currently?

ANSWER:

Question 5 (Carbon credits): Is an effective global market in carbon credits likely to develop that can support action in developing countries? Subject to these developments, should credit purchase be required/expected/allowed in the UK's long-term targets?

ANSWER: Carbon credits are not material emissions but rather financial instruments that stand in for putative reductions. They are calculated against an assumed baseline in the absence of the trade, so called "business as usual". If the Paris Agreement objectives are to be fulfilled the relevant baselines for international trades will be fairly allocated national emissions pathways that align with global climate stabilisation. Credit exchanges between nations would then be analogous to the Kyoto Protocol's Joint Implementation mechanism. The alternative model of the Clean Development Mechanism, where the baseline is defined as emissions growth, does not form a robust basis for trading within the temperature stabilisation objectives of the Paris Agreement. The CDM model would tend to inflate the net global emissions pathway.

If an international mechanism is agreed that does not inflate the cumulative global decarbonisation pathway then trading to achieve net zero compliance for the UK will have to identify projects that go beyond already challenging reductions for developing countries.

Part 3: Reducing emissions

Question 6 (Hard-to-reduce sectors): Previous CCC analysis has identified aviation, agriculture and industry as sectors where it will be particularly hard to reduce emissions to close to zero, potentially alongside some hard-to-treat buildings. Through both low-carbon technologies and behaviour change, how can emissions be reduced to close to zero in these sectors? What risks are there that broader technological developments or social trends act to increase emissions that are hard to eliminate?

ANSWER: The key point here is that demand has to reduce until either the mode (or food type) has changed to a low emission alternative or in some other way become zero carbon. "Hard to reduce" and "hard to treat" are by definition "hard" but not impossible. The "hard" here typically links to timely opportunities for making a technical transition to a zero carbon alternative. Certainly in some sectors technical substitution will take longer than in others, or will require a very different configuration of service. Where such cases do exist, managing absolute reductions in demand becomes pivotal (if we are to deliver on the Paris 1.5 to 2°C framing of mitigation). Given the highly uneven distribution of resource use, energy consumption and emissions within the UK population, such demand management needs to centre on how to organise a fair allocation of "hard to reduce" energy services. Adopting demand management opportunities early (if they deliver absolute, early and significant emission reductions) could extend the window for delivering the technical elements of a zero-carbon transition.

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It is also important to recognise a large difference in 'service' between the three sectors identified; there is clearly a difference between the percentage of the population impacted, and levels of acceptable 'rationing' for agriculture (and hence food) as this impacts on all of the population and is necessary for survival. Aviation on the other hand, is a service enjoyed by a much smaller percentage of the population, with a very large proportion (but not all) used for activities not required for survival or the betterment of society overall.

Despite the plethora of social science research around issues of climate change, there is little yet developed on distributional dimensions of national climate policy, including carbon rationing, in line with the scale of mitigation necessary to deliver on Paris. Two related (but now older) reports are:
https://www.flemingpolicycentre.org.uk/Tyndall2005.pdf
https://tyndall.ac.uk/sites/default/files/publications/twp136.pdf

As for pushing the technology envelope within the 'Hard' sectors, the papers outlined below discuss such opportunities in relation to the shipping sector:

1) There is no one solution available to the shipping industry that can provide the mitigation necessary and the implementation of a suite of technology options is required. Mitigation should be considered with respect to a specific ship type and size – for both retrofit and new build – and short term options include wind propulsion, slow steaming, cold ironing, voyage optimisation and waste heat recovery. In the long term, further reductions can be made by changing fuel to a low-carbon alternative, such as biofuels or fuel cells. These are discussed in:

https://www.tandfonline.com/doi/pdf/10.1080/17583004.2015.1013676?needAccess=true

2) However, increases in shipping demand will offset total reductions. Solutions to the global 0.5% sulphur cap in 2020 must also consider full life-cycle carbon reductions to avoid the lock-in of high-carbon options, such as with LNG, as discussed in:

https://www.sciencedirect.com/science/article/pii/S0959652617324721

Question 7 (Greenhouse gas removals): Not all sources of emissions can be reduced to zero. How far can greenhouse gas removal from the atmosphere, in the UK or internationally, be used to offset any remaining emissions, both prior to 2050 and beyond?

ANSWER: The approach adopted in the reports referenced in Q3 rejects using negative emissions to offset any CO_2 from energy. The reasoning for this position is described in the trouble with negative emissions The reports in Q3 include some small offset allowance whereby indigenous forestry compensates for the residual non-CO_2 warming related to agriculture.

The opportunities for 'negative emissions' to expand the carbon budgets to a 100/s$GtCO_2$ level remain highly speculative yet are ubiquitous in scenarios for greater than 50% chance of delivering on 2°C. Similar levels of quantitative uncertainty exist for positive carbon cycle feedbacks that would reduce the carbon budgets, yet these are almost universally

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excluded from emission scenarios. This suggests a community-wide bias in favour of delivering politically palatable rather more balanced scenarios. Removing negative emissions from scenarios increases mitigation rates for wealthier nations by an order of magnitude for the same temperature. See: what if negative emissions fail at scale

For a detailed and measured account of BECCS technologies, the implications and challenges of their deployment see Clair Gough, Patricia Thornley, Sarah Mander, Naomi Vaughan and Amanda Lea-Langton (Eds) 2018 *Biomass Energy with Carbon Capture and Storage (BECCS): Unlocking Negative Emissions*. There is potential for BECCS (or other negative emissions approaches) to contribute to offsetting residual emissions but attention needs to be paid to the scale (magnitude and timescale) of delivery assumed for such approaches and the level of optimism associated with these assumptions (see http://iopscience.iop.org/article/10.1088/1748-9326/aaaa02/meta; https://www.cambridge.org/core/journals/global-sustainability/article/challenges-to-the-use-of-beccs-as-a-keystone-technology-in-pursuit-of-15c/5E8AE2ECC9DCACB5DFE4B97BBE70476D; http://iopscience.iop.org/article/10.1088/1748-9326/11/9/095003/meta).

Furthermore, if negative emissions approaches are to have a role in staying within carbon budgets, action to promote and facilitate early deployment must commence immediately. In the case of BECCS this means establishing CCS infrastructure to support abatement across a variety of applications (such as hydrogen production, heat, industry) immediately. Investment decisions taken now could see first commercial CCS plants operational by the mid 2020s, with opportunities for BECCS following thereafter. Ensuring a tightly regulated and monitored supply chain to avoid system losses and ensure genuine negativity will be critical.

Question 8 (Technology and Innovation): How will global deployment of low-carbon technologies drive innovation and cost reduction? Could a tighter long-term emissions target for the UK, supported by targeted innovation policies, drive significantly increased innovation in technologies to reduce or remove emissions?

ANSWER: Setting mitigation in line with a fair UK contribution to the “well below 2°C” framing of climate change (without recourse to large scale negative emissions) would see mitigation significantly increased in the near-term.

Disaggregating such a global carbon budget to the UK increases mitigation to between 10-15% each year (depending on the exact apportionment regimes adopted) and starting immediately. This would require a profound shift in the productive capacity of society with resources and labour focussed on delivering a zero-CO_2 energy infrastructure and supply by 2035-40 (the reasoning and maths for this are in ref [1] of Q3).

Specifically in terms of innovation and technology, achieving 10-15% emission-reduction curve would require major policy change to begin almost immediately – achieving a 10-15% cut in energy demand in years 1-3 (see earlier discussion/references on carbon rationing in Q6). This would need to be followed by deep cuts in demand through tightened energy efficiency and operating practices in years 2-10 (including policies to avoid

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rebound). Within a decade, low/zero CO_2 energy would need to be penetrating deeply into the supply system – with full substitution soon after 2035 (and likely with three to four times the current levels of electricity generation). The UK's Industrial Strategy has the potential to support the development of low carbon infrastructure and low carbon innovation but this goal must be a central driving force in both the national and local level strategies if the significant transformation required is to happen and importantly, if we are not to lock in industrial and infrastructure development that actually increases our emissions.

The driver in all this will arise not from awaiting new low-carbon technologies, but from a comprehensive and equitable decarbonisation agenda driven at a national or ideally supra-national level.

Question 9 (Behaviour change): How far can people's behaviours and decisions change over time in a way that will reduce emissions, within a supportive policy environment and sustained global effort to tackle climate change?

ANSWER:

There is a substantial body of work on behaviour change in relation to emissions reduction. However, a key point that is often missed in this analysis is the distribution of high emitting behaviours across the population. Rather, 'the public' is often considered as homogenous with all needed to 'do their bit'. One option for tackling the need to significantly and rapidly reduce emissions is to have a more targeted and tailored approach in terms of those whose behaviours need to change. Building on the Chancel and Piketty report, if the top 10% of global emitters were to reduce the carbon footprint of their activities to that of a typical EU citizen, and if the other 90% were to make no reductions, global emissions would still fall by around one third compared with those of today. For 2°C there is a need to take such a targeted approach in the near term, as it is simply not possible to squeeze enough emissions out of median and lower income groups to deliver the necessary and ongoing rates of mitigation, all more so if preserving affordability and equality are considered.

Question 10 (Policy): Including the role for government policy, how can the required changes be delivered to meet a net-zero target (or tightened 2050 targets) in the UK?

ANSWER: **Repeated from Q8**:

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Specifically in terms of innovation and technology, achieving 10-15% emission-reduction curve would require major policy change to begin almost immediately – achieving a 10-15% cut in energy demand in years 1-3 (see earlier discussion/references on rationing in Q6). This would need to be followed by deep cuts in demand through tightened energy efficiency and operating practices in years 2-10 (including policies to avoid rebound). Within a decade low/zero CO_2 energy would need to be penetrating deeply into the supply system – with full substitution soon after 2035 (and likely with three to four times the current levels of electricity generation). The UK's Industrial Strategy has the potential to support the development of low carbon infrastructure and low carbon innovation but this goal must be a central driving force in both the national and local level strategies if the significant transformation required is to happen and importantly, if we are not to lock in industrial and infrastructure development that actually increases our emissions.

The driver in all this will arise not from awaiting new low-carbon technologies, but from a comprehensive and equitable decarbonisation agenda driven at a national or ideally supra-national level.

Part 4: Costs, risks and opportunities

Question 11 (Costs, risks and opportunities): How would the costs, risks and economic opportunities associated with cutting emissions change should tighter UK targets be set, especially where these are set at the limits of known technological achievability?

ANSWER: Reduce the discount rate to zero for impacts so that costs over time can be compared with upfront mitigation. Understanding discount rates (particularly those embedded in 'cost effective' mitigation models) needs to be transparent and costs tested when a zero discount rate is also included. Most IAMs use around 5% p.a. in contrast to the much lower values adopted on ethical principles by, for example, the Stern Review (2006). **This is one of the principal reasons 'negative emission technologies' post 2050 are found to be cheaper than emissions reductions today and hence ubiquitous in models.**

Question 12 (Avoided climate costs): What evidence is there of differences in climate impacts in the UK from holding the increase in global average temperature to well below 2°C or to 1.5°C?

ANSWER:

Part 5: Devolved Administrations

Question 13 (Devolved Administrations): What differences in circumstances between England, Wales, Scotland and Northern Ireland should be reflected in the Committee's advice on long-term targets for the Devolved Administrations?

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ANSWER: Disaggregating a national carbon budget to regions can be based on a range of apportionment criteria – population, grandfathering, GVA etc. However, given that the rapid and deep mitigation necessary for 2°C will be costly, there is a strong case for adjusting any regime with an equity-based coefficient, for example GVA/capita or something similar. Discussions with representatives from local government in Swedish Län and Kommuner suggest that grandfathering alongside a GVA/capita coefficient is probably more just than other apportionment regimes.

However, it is essential to note that, given how small even the highest end of the Paris compliant budgets are, significant action is needed across the UK. Planning now for this transition, through local and national industrial strategies and other planning processes has the potential to ensure that all DAs have the opportunity to prosper from the transition and are not left behind in terms of innovation and realignment of local economies.

Given that some sectors are hard to decarbonise (question 6) and there are variations in the economies for DAs (agriculture, industry, etc) specific targets focusing on energy-related sectors are more effective in relation to temperature targets. DAs that have more land area devoted to forests can mask CO_2 emissions from energy which should be avoided.

Part 6: CCC Work Plan

Question 14 (Work plan): The areas of evidence the Committee intend to cover are included in the 'Background' section. Are there any other important aspects that should be covered in the Committee's work plan?

ANSWER: The Committee's analysis should ensure that:
1) any scenarios considered with negative emissions (increasing the budgets) are in the minority , and that for each such scenario another includes additional positive carbon cycle feedbacks (reducing the budgets).

2) that equity is paramount in dividing the global 1.5 -2°C carbon budget to nations. This budget could be assumed to begin in Paris in 2015 (or arguably 1990, Rio in 1992, Kyoto in 1997 or Copenhagen in 2009) and that the apportionment be informed more by cumulative emissions per capita from the start date than the current (& highly inequitable) 2050 contraction and convergence. The current approach entrenches an increase in the existing inequality in cumulative emissions/capita (& hence relative responsibility for climate change) out to 2050.

3) Global emissions from deforestation and process cement should be separated from energy to enable some element of international equity to be considered in relation to them. The UK is an industrialised nation with established and cement-rich energy and transport networks alongside well-developed built environments across the industrial, commercial and domestic sectors. Despite this, the CCC currently make no allowance for the huge asymmetry in per capita cement use between wealthy nations with existing infrastructure (~150kg/capita in the UK) and poorer and industrialising nations rapidly building such an infrastructure (>1500kg/capita in China).

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In the near to medium term cement is set to remain the bedrock of physical infrastructure underpinning industrialisation, with no low-carbon alternative commercially available at the global scale (approaching 4.5 billion tonnes of cement produced per annum) within the coming two decades. Consequently, and despite process efficiency and other technical improvements (clinker ratios, CCS, etc.), significant and growing process emissions will unavoidably accompany development in poorer nations. By contrast cement use in wealthy nations will likely remain unchanged as it continues to facilitate the maintenance of and incremental change to existing infrastructures (the processes of decarbonisation may drive an important but still relatively small and near term increase in cement use).

The CCC's assumption that process emissions from cement production are solely the responsibility of individual nations risks stifling the rates of development of poorer and less industrialised countries. Penalising such nations for their later development is inconsistent with the equity dimension of Paris and other climate change agreements. Acknowledging this, process emissions from cement are here considered as a global, rather than national, overhead. This does not absolve those nations using cement from responsibility, but rather provides an incentive for all nations to drive towards a more efficient use of cement, lower process emissions from cement production and the more rapid development of low-carbon cements and alternatives.