## Response from Professor Jon Gibbins

Director, UK CCS Research Centre
Professor of Power Plant Engineering and Carbon Capture, University of Sheffield

### 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: Many of the IPCC SR1.5 scenarios have extended periods of net negative emissions. If it does turn out to be necessary, the UK would presumably need to participate in delivering these net negative emissions, especially if they are agreed on as a global policy, and should prepare for this as well as for just net zero emissions.

In this context it is important to consider what might be reasonable levels of global net negative emissions. Obviously very high rates of negative emissions, particularly if these rely on a large element of BECCS, may be infeasible or involve difficult trade-offs. In general, delivering lower rates of net negative emissions for longer periods to get the same amount of net $CO_2$ removal would be more socially, environmentally and economically sustainable and would make better use of the infrastructure required.

In particular, the Committee should examine to what extent the very high negative rates leading up to 2100 in the overshoot pathways explored in the SR15 report (Figure SPM.3b, P4) are an artificial consequence of using 2100 as the end of the scenario period. All scenarios should be considered in their entirety, through to their eventual end point, which in all cases would eventually be a gradual levelling off at near net zero emissions.

Obviously it may also be desirable to actively reduce atmospheric $CO_2$ concentrations still further to achieve lower long-term average global temperature increases, but this should be clearly differentiated from the efforts required to stabilise at 1.5 degrees.

**Question 2 ($CO_2$ and GHGs):** Carbon dioxide and other greenhouse 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: No comment

### 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: No comment

**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: CCUS has been identified as a major enabling technology for global $CO_2$ emissions reduction but the IEA has recently noted how, despite the importance of CCUS, there has been a major disparity between funding for CCUS and renewables, stating that "The total level of public funding directed to CCUS project deployment over the last 10 years is just 3% of that spent on subsidies for renewable power generation in 2016 alone."

The UK is one of a very few countries currently planning to deploy CCUS at scale. Expenditure by the UK on CCUS will therefore have a much greater impact on building global capacity than the same expenditure on renewables, because the latter are already well-demonstrated and developed at scale while CCUS is not, and the UK's contribution to CCUS deployment will be a major part of the global efforts to develop a proven CCUS option for future climate change mitigation. Furthermore, if initial projects are undertaken on an open-access basis then there can be widespread international learning from them. The UK can also demonstrate a more rational allocation of public funds between CCUS and other technologies, which will encourage other countries to do the same and correct the problem that the IEA notes above. Of course, developing 'conventional' CCUS also directly aids in the development of BECCS and DACCS, important negative emissions technologies.

**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: No comment.

## 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: Greater attention should be given to direct air capture with $CO_2$ storage (DACCS) for residual emissions of this type. There are no obvious limits on the amount of direct air capture that can be achieved, unlike BECCS, especially given that it can be undertaken anywhere in the world where suitable energy sources and secure CO2 storage are available. Costs for DACCS may appear to be high but marginal abatement costs using other approaches for the applications described above may also be significant, and it provides a clear upper-limit cost. DACCS has the advantage of being able to operate 24/7 and anywhere in the world rather than being applied at dispersed and possibly mobile locations that may also emit relatively infrequently. Detailed 2018 engineering and cost analysis (https://www.cell.com/joule/fulltext/S2542-4351(18)30225-3 ) for a 1 Mt-$CO_2$/year direct air capture plant by Carbon Engineering reported levelised costs of $94 to $232 per ton $CO_2$ removed from the atmosphere. To put this in the context of oil prices, it is the equivalent of roughly $42 to $102 additional cost on a barrel of oil (not including $CO_2$ transport and storage). Given that fossil fuel prices are likely to be significantly depressed if there is a global target of achieving net zero or lower GHG emissions then this mark-up for DACCS could well be sustainable. The UK would be in a good place to develop and deploy DACCS in future CCUS clusters.

**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: See previous answer. Provided the GGR technologies do not rely on finite natural resources and actually deliver verifiable and secure reductions (as for DACCS), then quite widespread use is possible and may well help to reduce the costs of achieving net zero, or net negative, emissions.

Where biomass is available in ‘industrial’ quantities and forms it is best used for BECCS. Rather than using biomass without BECCS, e.g. for ‘low carbon’ transport or heating fuels, carbon-free energy vectors should be used instead. Even if natural gas or petroleum products are substituted for biomass, their lower $CO_2$ emissions per unit energy than biomass would still make reserving biomass use for BECCS preferable.

Deploying BECCS most effectively requires that it be used to produce a carbon-free energy vector: electricity, hydrogen or heat (but heat viable only in limited amounts and locations). Electricity production with BECCS is clearly technically feasible, but there appears to be no planning for it in current UK future electricity scenarios. In particular, BECCS for power would be most cost-effective if run at high load factors and this does not appear to be allowed for in future UK electricity supply scenarios dominated by intermittent renewables. It is also important that suitable BECCS power plant sites, likely to be those of former coal plants, are retained as usable national assets, if not also the existing coal plants themselves where these are suitable for conversion.

The alternative, hydrogen production with BECCS, relies on thermal gasification for conversion of most available biomass sources. Biomass gasification to produce a gas suitable for shifting to hydrogen has not yet been demonstrated at scale and there are

**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?

intrinsic reasons why it is difficult to do so, associated with the low biomass calorific value and low melting point ash. The variable nature of biomass also presents problems. Biomass upgrading followed by oxygen blown entrained flow gasification is a possible solution, as is co-gasification with fossil fuels, but both are still largely unproven. Robust gasification technology demonstrations, at an appropriate scale and for realistically long periods, are therefore required before BECCS to hydrogen can be relied on as an alternative to BECCS to electricity. And even then, BECCS for power may well prove to be the cheaper option if not crowded out by alternative generation deployment.

**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: Targeted innovation for CCUS in the UK, in support of national targets, could help drive very significant global innovation, especially since we are starting from almost no deployment of key types of CCUS (i.e. power, BECCS, DACCS, CCS hydrogen).

CCUS is different from other technologies in that only a few (5-20?) big projects can be expected globally over the next decade and there would then would need to be a huge increase in deployment, rapidly and at a scale of hundreds of projects, to meet agreed-upon climate targets.

Making these few near-term projects, which will be largely publicly-funded (through direct government support or indirectly via permitted charges on consumers), as open-access as possible for information exchange is a key enabler for further innovation and cost reduction. The government should ensure that explicit and robust contractual measures are in place to make sure that this happens as a condition of public support.

Open access to information and the plants themselves gives a fast track to deploy innovations of all kinds, including through in-service upgrading, plus critical information exchange, in both directions, with national and international research initiatives such as Mission Innovation and pilot testing e.g. International Test Center Network, ACT - Accelerating CCS Technologies.

For post-combustion capture (PCC) full-scale projects, which may often be retrofits to existing power plants or industrial sources such as furnaces and cement plants, being open-access requires the use of a non-proprietary solvent, at least for an initial period so that meaningful knowledge transfer, in both directions, is possible. Experience with previous UK CCS FEED studies and the Boundary Dam and Petra Nova projects in North America shows that when proprietary solvents are used the capture plant becomes a 'black box' with most of the significant transferrable knowledge redacted in reports.

But subsequently open-access plants could upgrade to the latest solvents, including proprietary, throughout their lives. A period of global open-access PCC plant deployment with multiple solvents trialled would therefore also help to achieve a PCC market with a sufficient number of competent suppliers with diverse products to give choice, competition and a minimal risk of a class failure (e.g. from environmental emission issues).

**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?

Open-access enables knowledge exchange to reduce costs at all stages – feasibility, FEED, EPC, commissioning and initial operation. It may well be that, because of the greater competition in procurement that it allows, costs will be reduced even for the first projects. In any case, open-access gets much better value for government expenditure on deployment and R&D and greatly increases the rate at which CCS technologies will improve. Reciprocal open-access arrangements with other countries would also give very significant gearing for UK investment in accelerating CCUS.

**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: No comment.

**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: CCUS is a major enabler for net-zero or net-negative emissions. As noted above, it cannot be assumed that net-zero will be sufficient in the future given IPCC SR1.5 analysis. Government policy needs to be shaped around a plan to deliver at least two UK CCUS clusters in the 2020s in line with previous CCC recommendations. Aiming to deliver just one cluster would involve a serious risk, in the event of any delays, that nothing is deployed in time. The UK also has two natural sets of interlinked CCUS clusters, both with extensive emissions and supporting large amounts of employment, on the East and West coasts, and it is important to progress these in parallel. The output from the CCUS Cost Challenge Taskforce and the recent Accelerating CCUS Summit suggests that, if suitable government policy and market support measures are in place then, by analogy with large-scale renewables, industry, supported by R&I organisations, will deploy at scale and drive cost reduction.

## 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: Most studies agree that tighter targets will require more widespread use of CCUS, including BECCS and DACCS, and for this, the UK has intrinsic advantages compared to most other countries. We have extensive CCUS opportunities because of the proximity of industry clusters in coastal regions close to secure offshore geological storage sites for $CO_2$. Also, the UK is in a leading global position for policy development on CCUS deployment and has the necessary industrial and research and innovation base on CCUS to support deployment and build a world-leading industry in the area.

| |
|---|
| **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: No comment. |

**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? |
| ANSWER: No comment. |

**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 statement in the Background, "The actions needed in the near term that would be consistent with achieving the long-term targets", covers a very broad area. Specifically, there is tension when near term marginal abatement costs are lower for certain established technologies compared to marginal abatement costs for other, newer, technologies that may be more important for ultimately achieving net zero or net negative emissions, with CCS being an obvious example, especially of the latter. The Committee should examine how a balanced portfolio of support actions for different UK technology options can be implemented, which prioritises developing technologies for future requirements as well as short-term costs. Note also the IEA statistics on the current imbalance between renewable and CCUS funding; the climate goals are sufficiently ambitious that a range of technologies will need to be fully explored and employed.<br><br>In addition, it is essential that viable sustainable net-zero, and optionally net-negative, energy systems are examined and that planning works back from these to ensure a reasonable progression from where we are now. The present plans appear to be to maximise the deployment of intermittent renewables and only later to consider how to cut the remaining emissions and also deploy GGR technologies at scale. This may not be the most cost-effective or strategic option. |