Note on "Note on 'Assessing the relative costs of high-CCS and low-CCS pathways to 1.5 degrees'", Myles Allen, 13 Dec 2023

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Producing reliable statements about the likelihood of future events is extremely difficult and fraught with nuance, so it is good to probe results, seek clarification and be precise. We would like to address the statements made by Allen and offer some clarification on the methodology of our study.

Given that all the scenarios in our report require a hundred-fold scale-up of CCS to 2050, we wholeheartedly agree with Allen that rapidly scaling up CCS investment and deployment should be an urgent priority.

For clarification, it is incorrect to say that any output data (or plot thereof) from our study "shows no relationship between the level of CCS deployment in 2050 and the cost of useful energy up to about 10 GtCO2 per year". Our study does not show this and cannot show this, due to methodological choices and approximations used to estimate scenario costs, which we will expand on below.

For clarification, it is also incorrect to say that any output data (or plot thereof) from our study shows that "Above 10 GtCO2 per year of CCS in 2050 there appears to be a modest increase in useful energy cost in 2050, although again there is no obvious trend from 10 to over 25 GtCO2 per year."

The above statements made by Allen appear to result from a misunderstanding of the methodology used in our report. Our study aims to estimate relative scenario costs. The approximations used to do this are only valid when comparing low-CCS and high-CCS scenarios; they are not valid for comparisons with mid-CCS scenarios. While we recognise the value of further understanding mid-CCS scenarios, doing so in a robust way would require further analysis.

By modelling a case where CCS costs are very low (much lower than observed currently), and remain very low in future, our study produces a justifiable lower bound on the expected difference in costs between low- and high-CCS scenario groups. This is because, although there is significant variation in estimated scenario costs due to many other factors besides CCS costs (i.e., all other technology deployment and cost trajectories), we know that the more CCS a scenario contains, the higher the expenditures on CCS will be, and therefore, if even when CCS costs are very low there is a large and clear difference between estimated scenario costs, this difference will only grow larger as CCS cost assumptions are raised to more realistic levels. In other words, when comparing low- and high-CCS scenario costs, we can be confident that the estimated cost difference is large enough to comfortably dominate both the scenario cost variations unrelated to CCS, and the entire uncertainty range in CCS costs currently found in the literature. The cost difference between mid-CCS scenarios and both low- and high-CCS scenarios is smaller, and so (using deterministic technology costs as we do), it is impossible to tell whether cost differences are due to CCS costs or other factors. A more sophisticated approach to technology cost uncertainty would be required to produce reliable results on this question.

Thus, the lower-bound methodology used in our report is not suitable for addressing mid-CCS scenarios costs. The method is not designed to be able to distinguish between scenario costs with enough fidelity to produce scientifically meaningful results on this question, and we have not attempted to do so. While it could be true that there is "no relationship between the level of CCS deployment in 2050 and the cost of useful energy up to about 10 GtCO2 per year", as Allen states, our study does not show this, nor does it attempt to address the issue.

Consider the following figure, which we have produced to help demonstrate our approach:

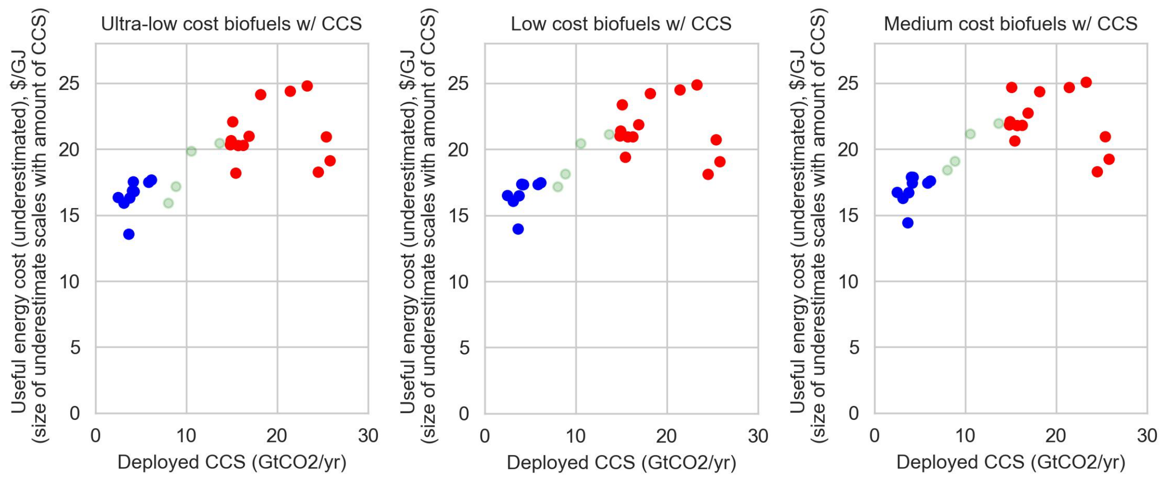

Figure 1: estimated useful energy costs versus CCS deployment in 2050 for the IPCC AR6 scenarios selected by Bacilieri et al, 2023, using three different cost values for "Liquids from biomass w/ CCS" (Ultra-low cost: 1.6 $/gge, Low cost: 3.2 $/gge, Medium cost: 4.8 $/gge). Other costs in the model are "main case" costs. All useful energy cost values plotted here are underestimates because CCS costs are set artificially low – this ensures that any large observed cost differences between groups are insensitive to CCS cost assumptions over the entire range of possible CCS costs found in the literature. The size of the underestimate scales roughly with CCS deployment. Colours indicate classification in that study: blue = "low", green = "mid", red = "high". Green points are faded to indicate that they cannot be used to perform reliable comparisons with the low- or high- groups, because scenario cost variation due to non-CCS-related factors could be larger than that due to CCS cost uncertainty.

Figure 1 shows the same model output data plotted by Allen, but for three different input cost assumption values for the variable "Liquids from biomass w/ CCS" in the model. The left plot has the cost of these biofuels with CCS set to $1.6/gge, which is the lowest value of the range estimated in AR6 (see Table 3 in our report). The middle plot has the cost set to $3.2/gge (i.e., 2 x 1.6). The right plot has the cost set to $4.8/gge (i.e., 3 x 1.6), which is around the mid-point of the range estimated in AR6.

The subplots in Figure 1 demonstrate that the locations of the useful energy cost points for mid-CCS scenarios (green) relative to the low- (blue) and high- (red) CCS scenario groups are sensitive to CCS cost assumptions. They therefore cannot be used to make reliable and meaningful statements about cost differences between these groups. Note that the relative locations of the low- (blue) and high- (red) CCS scenario cost points do not exhibit the same sensitivity. This is because between these two groups, scenario cost variation due to non-CCS-related factors is dominated by variation due to CCS costs *even at very low CCS costs* (i.e., the red dots are systematically higher than the blue dots on the left plot), and so as CCS costs increase, the average cost difference also increases, and the relative positions remain the same (i.e., the red dots remain systematically higher than the blue dots on the other plots). The red and blue points move a bit, but the relative locations of the clusters remain stable, and so our main findings remain valid.

Therefore, it is impossible to make any reliable and meaningful claim about the relative costs of mid-CCS scenarios based on the methods used in our report. We hope this clarification is useful, and welcome further study in this field.