Note on "Assessing the relative costs of high-CCS and low-CCS pathways to 1.5 degrees", Andrea Bacilieri, Richard Black, Rupert Way, 4 December 2023, Oxford Smith School of Enterprise and the Environment, Working Paper No. 23-08 ISSN 2732-4214 (Online)

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Bacilieri et al present an analysis of costs of carbon capture and storage (CCS), including evidence that CCS costs have failed to decline over time or with deployment in the way that renewable energy costs have done.[1] This is an important finding, and should prompt questions why policies used to date to incentivise the deployment of CCS have failed to drive down costs. Given even the lowest CCS scenarios considered by Bacilieri et al require a hundred-fold increase in CCS deployment to achieve the goals of the Paris Agreement, dwarfing in percentage terms the increases required in many other mitigation technologies, designing policies[2] to reduce the cost of CCS with deployment must be an urgent priority.

Geological CO_2 storage (combining, as Bacilieri et al do, point-source capture and carbon dioxide removal) has long been recognised[3] as a uniquely important mitigation technology because (apart from remineralisation and ocean alkalinisation, whose potential and environmental side-effects remain unknown) it provides the only way of permanently correcting for cumulative over-production of CO_2 from fossil sources ("carbon budget overshoot") which now looks inevitable.[4]

The way the data are presented in the Bacilieri et al study, however, gives the impression that any level of CCS deployment other than a very low scenario of around 4 billion tonnes of CO_2 per year ($GtCO_2$/year) in 2050 would be "highly economically damaging". This conclusion is suggested by the separation of scenarios into a "low-CCS" and a "high-CCS" group, averaging around 4 and 20 $GtCO_2$/year, respectively (blue and red dots in the figure). Communications regarding this study focussed on the absolute difference between the two, which is large because of the scale of total energy system costs, although the report itself acknowledges that the cost-differential is only about 20%.

Imposing cost assumptions on technology deployment pathways derived from cost-optimised Integrated Assessment Models (IAMs) is methodologically problematic (because these cost assumptions may not be consistent with costs assumed in the IAMs themselves) but nevertheless represents a reasonable approach if we consider these IAM scenarios simply as self-consistent possible futures, given the world is highly unlikely to follow a cost-optimal trajectory in any case.

Taking the study at face value, however, the actual data (kindly provided by the authors) inevitably tells a rather more nuanced story than the summary and reporting suggested. The figure below (replotted from numbers shown in figures 2b and 6b of Bacilieri et al) shows no relationship between the level of CCS deployment in 2050 and the cost of useful energy up to about 10 $GtCO_2$ per year. Differences in total energy system cost between "low-CCS" and "mid-CCS" scenarios are related more to differences in final energy demand rather than the level of CCS deployment. Low demand scenarios naturally involve lower energy system costs, but may be difficult to achieve for non-monetary reasons.

Above 10 $GtCO_2$ 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 $GtCO_2$ per year. In all cases, the small numbers of cases considered imply a heavy dependence on the scenario selection. For example, the cluster of three very-high-CCS and relatively-low-cost scenarios represent all the cases included from one model (IMAGE 3.2), while the four IAMs in the "mid-CCS" category may well be unrepresentative (in the original database, most scenarios fall into this category, while in the subset selected for the study, they are the smallest group).

Hence, while there is some evidence from the IPCC scenarios that extreme reliance on CCS to allow fossil fuel usage to continue at 50% or more of the current rate in 2050 would be economically damaging, there is no evidence that the cost of useful energy is significantly impacted by the level of reliance on CCS up to 10 $GtCO_2$ per year around the date of net zero, which is around 25% of current emissions or the scale of the current natural gas industry. This is also consistent with independent estimates of the scale of "hard-to-abate" emissions for which CCS represents a more cost-effective mitigation option than substitution.[5]

Achieving climate goals requires both a rapid scale-up of CCS and action to reduce the rate of fossil fuel use, yet investment in CCS still represents well under 1% of overall investment in low-carbon solutions.[6] This is, in percentage terms, at least an order of magnitude lower than it should be to reflect the role of CCS in mitigation even for low-CCS deployment pathways. Given the urgency of CCS deployment, and the need for supportive policies to drive CCS costs down the learning curve, it is imperative to avoid giving the impression that CCS can or should only make a minor contribution to meeting our energy needs and climate goals in 2050.

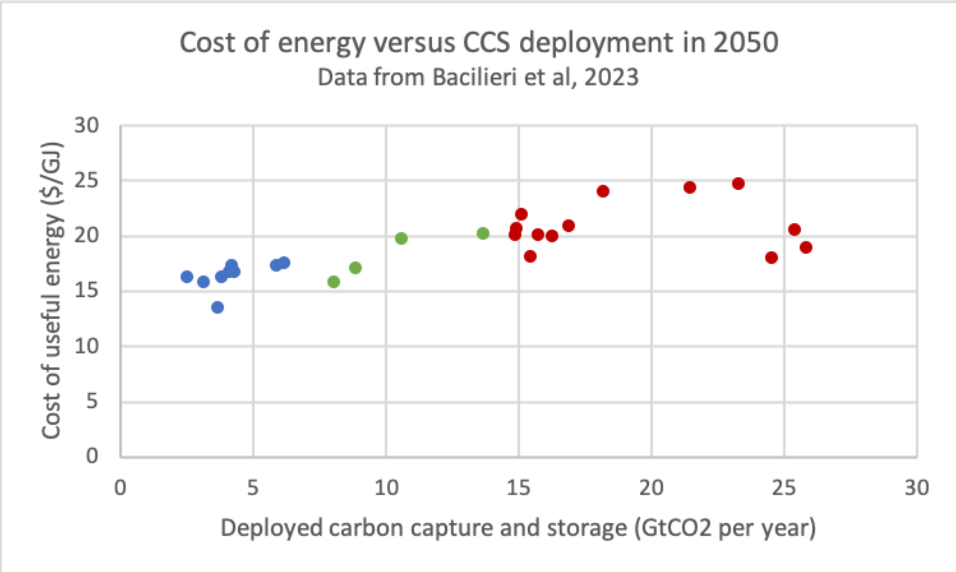

Figure: Cost of useful energy versus level of CCS deployment in 2050 for the IPCC AR6 scenarios selected by Bacilieri et al, 2023. Colours indicate classification in that study: blue = "low", green = "mid", red = "high"

1. Way, R., Ives, M., Mealy, P. & Farmer, J. D. *Empirically grounded technology forecasts and the energy transition*. https://www.inet.ox.ac.uk/publications/no-2021-01-empirically-grounded-technology-forecasts-and-the-energy-transition/ (2021).
2. Jenkins, S., Mitchell-Larson, E., Ives, M. C., Haszeldine, S. & Allen, M. Upstream decarbonization through a carbon takeback obligation: An affordable backstop climate policy. *Joule* **5**, 2777–2796 (2021).
3. Kriegler, E. *et al.* The role of technology for achieving climate policy objectives: overview of the EMF 27 study on global technology and climate policy strategies. *Climatic Change* **123**, 353–367 (2014).
4. Lamboll, R. D. *et al.* Assessing the size and uncertainty of remaining carbon budgets. *Nat. Clim. Chang.* **13**, 1360–1367 (2023).
5. Della Vigna, M., Stavrinou, Z., Bhandari, N. & et al. *Carbonomics: The future of energy in the age of climate change*. 44 https://www.goldmansachs.com/intelligence/pages/gs-research/carbonomics-f/report.pdf (2019).
6. Global Low-Carbon Energy Technology Investment Surges Past $1 Trillion for the First Time. *BloombergNEF* https://about.bnef.com/blog/global-low-carbon-energy-technology-investment-surges-past-1-trillion-for-the-first-time/ (2023).