

Research brief: Ensuring feasible CO₂ geological storage projections in climate mitigation pathways

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Summary

Integrated Assessment Models (IAMs) play a central role in climate policy by producing the climate change mitigation pathways used by governments and the IPCC. Many pathways that limit warming to 1.5°C or 2°C depend on significant expansion of CO₂ geological storage often reaching around 15 GtCO₂ per year by 2100. However, questions have arisen about the near to mid-term feasibility of these projected growth rates, particularly as global storage rates were only around 0.045 GtCO₂ per year in 2023.

We assessed how six major IAMs currently represent geological storage and examined whether recent improvements have strengthened the realism of projected deployment pathways. This research brief distils the key messages of the open access publication⁷. We find that:

1. **Future CO₂ geological storage deployment depends not only on scenario assumptions, but which IAM is used.** IAMs use three assumptions to constrain future deployment: geological storage potential, technology deployment rates and storage costs.
2. **The global CO₂ geological storage resource remains highly uncertain.** There is no scientific consensus on the physical limits of global CO₂ geological storage potential.
3. **IAMs may underestimate the true cost of CO₂ geological storage.** Many CO₂ geological storage cost assumptions used in the models are based on outdated evidence and may underestimate real-world costs.
4. **New deployment-rate constraints are reshaping CO₂ geological storage projections.** Annual limits on CO₂ geological storage deployment have only recently been introduced into many IAMs to prevent unrealistically rapid scale-up.
5. **IAM assumptions evolve faster than the documentation that describes them.** Projections can date quickly and establishing what a model currently assumes often means contacting the modelling teams directly.
6. **Most IAMs overlook the growing importance of international CO₂ transport and storage networks.** Cross-border CO₂ transport and storage infrastructure remains poorly represented.

In short: IAMs are becoming more realistic about CO₂ geological storage deployment, but many still rely on outdated assumptions about storage potential, costs and subsurface constraints.

To ensure robust mitigation pathways the next generation of climate change mitigation scenarios requires updated and IAM-ready geoscience datasets and workflows. Addressing these gaps requires action from both the IAM and CO₂ geological storage research communities, as well as decision-making groups including funders, regulators and policymakers.

Study background and context

Projections of how much CO₂ the world will need to store underground to limit climate change come from detailed-process Integrated Assessment Models (IAMs). These IAMs are computer models that link the global economy, the energy system,

land use and the climate in a comprehensive approach. An IAM identifies the most efficient pathway to meet a defined temperature target (such as 1.5°C or 2°C mean global surface temperature rise)¹, comparing the cost of options for reducing or removing emissions while accounting for resource and deployment constraints. CO₂ geological storage

¹ Earth System Models determine the total cumulative CO₂ emissions (carbon budget) compatible with a specific

temperature target, which IAMs then use as a constraint within their climate change mitigation pathways.

is one option among many to mitigate or remove CO₂ emissions. How much geological storage an IAM deploys depends on the costs, limits and policy assumptions that the model has been provided with.

The last IPCC assessment report (AR6, published in 2022) drew on climate change mitigation pathways submitted by many IAMs. Half of these pathways required more than 15 billion tonnes of CO₂ (15 Gt) to be stored annually by 2100². This is a sharp contrast with current levels of deployment: in 2023, the world stored 0.045 Gt³. Meeting these pathways would therefore mean scaling up more than 300-fold in 77 years.

The near to mid-term feasibility of such scale-up has been questioned⁴. However, it is hard to disentangle the process and assumptions by which IAMs arrive at such figures. IAMs are complex, and the teams behind each IAM update their models regularly to reflect new evidence and to respond to criticism of earlier scenarios.

In our new study⁵, we examine in detail how six IAMs project CO₂ geological storage, including the structures, mechanisms, data and assumptions in each IAM that inform deployment.

Findings

1. Climate change mitigation pathways depend on significant expansion of CO₂ geological storage, but projected deployment varies widely across models and scenarios. Half of these pathways require at least a 300-fold increase in CO₂ geological storage this century, yet projections range from no deployment at all to around a 700-fold expansion by 2100. Deployment levels depend not only on scenario assumptions but also on the structure of individual IAMs. Across models, three assumptions largely determine the bounds of future deployment: geological storage potential, deployment rates and storage costs.

2. IAMs have significantly improved the way they represent CO₂ geological storage, particularly by incorporating deployment-rate constraints.

Four of the six IAMs examined have introduced scale-up limits since IPCC AR6 in response to concerns that earlier pathways implied unrealistically rapid deployment. These upper limits, which can range from 5 to 35 GtCO₂ globally in a particular year, are likely to reduce projected future deployment and improve the realism of climate change mitigation pathways.

3. Key assumptions on CO₂ storage capacity and costs remain highly uncertain and are often based on outdated evidence.

There is no scientific consensus on the physical limits of global CO₂ geological storage potential and estimates of regional storage capacity can differ by more than an order of magnitude between IAMs. Similarly, many models continue to use storage cost assumptions derived from studies more than a decade old, typically assuming costs of \$2-20 per tonne of CO₂ stored. Recently published estimates span a far wider range than this: assessments that account for monitoring requirements reach \$35 per tonne, and under certain subsurface pressure conditions costs can run as high as \$147 per tonne. Most IAM assumptions sit at the bottom of this range, and when one modelling group revisited storage costs in their own IAM, projected storage fell by over 100 Gt⁶.

4. Many of the CO₂ geological storage projections most frequently cited today are already out of date.

The scenarios assessed in IPCC AR6 were produced using IAM versions dating largely from 2019-2021, and every model examined in this study has since been updated. Several of these updates are expected to reduce future deployment projections. However, because documentation, source code and input datasets often lag model development, understanding current

² The median 2100 projections for C1, C2, C3 and C4 scenarios were 14.1, 15.9, 14.3 and 15.9 GtCO₂yr⁻¹ respectively.

³ Gao & Krevor. 2025.

<https://doi.org/10.5281/zenodo.18016847>

⁴ Kazlou et al. 2024. <https://doi.org/10.1038/s41558-024-02104-0>, Zhang et al. 2024.

<https://doi.org/10.1038/s41467-024-51226-8>, Lane et al. 2021. <https://doi.org/10.1038/s41558-021-01175-7>

⁵ de Jonge-Anderson et al. 2026.

<https://doi.org/10.1038/s43247-026-03901-5>

⁶ Smith et al. 2021.

<https://doi.org/10.1016/j.ijggc.2021.103367>

assumptions remains challenging, limiting transparency for researchers and policymakers.

5. **Current IAMs may not adequately represent the growing importance of international CO₂ transport and storage networks.** Most assume that captured CO₂ must be stored within the same model region where it is captured. As a result, emerging transboundary storage arrangements, including those being developed in the Asia-Pacific region and elsewhere, are largely absent from modelled pathways.

6. **Improving future climate pathways requires closer collaboration between IAM developers and the CO₂ storage research community.** Many limitations identified in current models stem from a lack of up-to-date, model-ready geoscience datasets. Priority areas include transparent project-level storage cost data, updated storage resource assessments, and datasets describing injectivity, pressure limitations and deployment feasibility. Providing these data in formats that can be readily incorporated into IAMs will help ensure that future climate scenarios reflect the best available evidence.

Recommendations to researchers:

IAM teams:

1. Consider anchoring annual deployment limits on growth models.
2. Either represent cross-regional CO₂ transport or reassess regional aggregation so the grouping logic is compatible with realistic transport and storage.
3. Document post-AR6 updates in a form that policy audiences can find and interpret.

CO₂ storage teams:

4. Publish CO₂ geological storage assessments in formats that modelling teams can adopt directly - a recent global assessment⁷ is the example to follow.
5. Prioritise research on the parameters currently absent from model constraints: injectivity limits, pressure build-up, historic project failure rates and investible potential.

Recommendations to decision-makers:

Policymakers:

1. Treat the projections reported in IPCC assessments as scenarios underpinned by specific assumptions rather than a forecast or a target.
2. Avoid anchoring near-term national CCS targets on pathway values for 2030-2050 without checking them against growth-constrained analyses.
3. Adopt a range of cost estimates (including high-end ones) when assessing future CGS deployment and apply these across different pathways and scenarios.

Funders and regulators:

4. Encourage the disclosure of project-level storage costs and realised prices while preserving legitimate commercial confidentiality.
5. Continue to fund national and regional CO₂ geological storage resource assessments, published in a standardised and reusable form.

⁷ Gidden et al. 2025. <https://doi.org/10.1038/s41586-025-09423-y>

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