Updated CO_2 storage capacity estimates for saline aquifers in Indian sedimentary basins

Introduction

India's commitment to achieving net zero emissions by 2070 places carbon capture and storage among the technologies expected to play a substantial role in decarbonising hard-to-abate sectors such as steel, cement and power. Meeting this target is estimated to require storing between 400 and 820 Mt-CO_2 per year by 2050 under 1.5°C scenarios, and 280–570 Mt-CO_2 in the 2 °C scenarios [Singh et al., 2024]. Moreover, the International Energy Agency estimates that India could account for a fifth of the world's CCS market by 2060 [IEA, 2021]. Deep saline aquifers represent by far the largest resource amongst the geological storage options available in the country. However, they remain the least characterised, since, unlike depleted oil and gas fields, they lack legacy subsurface data built up over decades of hydrocarbon production [Vishal, Chandra, et al., 2021].

Earlier national assessments of saline aquifer capacity in India relied on globally derived storage efficiency factors, following methodologies such as the US Department of Energy's approach, and arrived at a total effective capacity of around 291 Gt of CO_2 across all classified basins [Vishal, Verma, et al., 2021]. While useful as a first order estimate, these efficiency factors were not derived from Indian reservoir conditions and did not address how quickly this capacity could realistically become accessible for injection. This study, carried out as part of a broader effort to develop CO_2 storage supply cost curves for India, updates these saline aquifer estimates using storage efficiency factors obtained from reservoir simulations of Indian formations. Furthermore, it integrates them into a dynamic capacity analysis that traces how storage availability evolves through 2070, based on a S-curve approach.

Methodology

Effective storage capacity in saline aquifers was estimated using a two step approach. A representative single well reservoir model was built using subsurface data from Indian saline formations and simulated over a 35 year injection period from 2025 to 2070, with free phase CO_2 saturation assumed to be zero prior to injection. Generally saline formations are close to hydrostatic pressure before injection begins, and thus the simulations were constrained by allowable pressure buildup above the original formation pressure, set at 15% for the base case and at 10% and 20% for the pessimistic and optimistic cases respectively [Verma and Vishal, 2024]. This is consistent with limits used in global studies to manage geomechanical risk [Rutqvist et al., 2016; Vilarrasa et al., 2019]. The resulting storage efficiency factors were applied to the pore volumes of nineteen sedimentary basins, classified into Category I basins with proven commercial hydrocarbon production, Category II basins with known but uncommercialised hydrocarbon occurrence, and Category III basins that remain largely unexplored [DGH, 2017].

Static volumetric estimates describe the total resource in place but fail to capture how storage availability evolves over time as projects are developed and reservoirs are accessed. To address this, an S-curve deployment profile was developed in which approximately 10% of the ultimate annual storage capacity becomes accessible by 2035, rising to 50% by 2045 and around 90% by 2055, reflecting realistic timelines for regulatory approval, reservoir conversion and infrastructure development. This profile was informed by the proximity of large point sources of CO_2 to each basin, since clusters with substantial nearby emissions, such as those around the Cambay and Mumbai Offshore basins, are expected to justify earlier infrastructure investment than more remote or less characterised basins [Vishal et al., 2023].

Results and Discussion

The updated effective storage capacity for saline aquifers across India's sedimentary basins are shown in Table 1. In the base case, the total effective capacity is estimated at 193.9 Gt of CO_2, ranging from 89.7 Gt under pessimistic assumptions to 297.6 Gt under optimistic ones. Category I basins, despite covering a comparatively small area, contribute around 76 Gt in the base case because of their favourable reservoir quality, with Cauvery, Krishna-Godavari and Mumbai Offshore emerging as the largest individual contributors. Category II and Category III basins add a further 52 Gt and 65 Gt respectively. The Kerala-Konkan-Lakshadweep basin alone accounts for nearly 37 Gt, the single largest capacity of any basin in the country, though its Category III status means this figure carries considerably more uncertainty and would need further characterisation before it could be relied upon for planning.

Table 1 *Updated effective CO_2 storage capacity (in gigatonnes) in deep saline aquifers across Indian sedimentary basins, by basin category, derived from reservoir simulation-based storage efficiency factors.*

Basin category	**Storage Capacity (Gt)**		
	Pessimistic	*Base case*	*Optimistic*
Category I basins (7)	35.3	76.2	117.0
Category II basins (5)	24.2	52.3	80.3
Category III basins (7)	30.2	65.4	100.3
INDIA (total)	89.7	193.9	297.6

These updated figures are broadly consistent with, though somewhat more conservative than, the previous national estimate of around 291 Gt. The updated figures build on the previous estimates by using India-specific reservoir simulation-based efficiency factors, rather than relying on global averages. The optimistic case of 297.6 Gt obtained here sits close to the previous estimate, while the base case reflects the more constrained pressure buildup limits considered appropriate for Indian formations. This suggests that while the broad scale of India's saline aquifer resource is confirmed, the range of outcomes is wide enough that basin level characterisation, rather than national totals, should guide near term investment decisions.

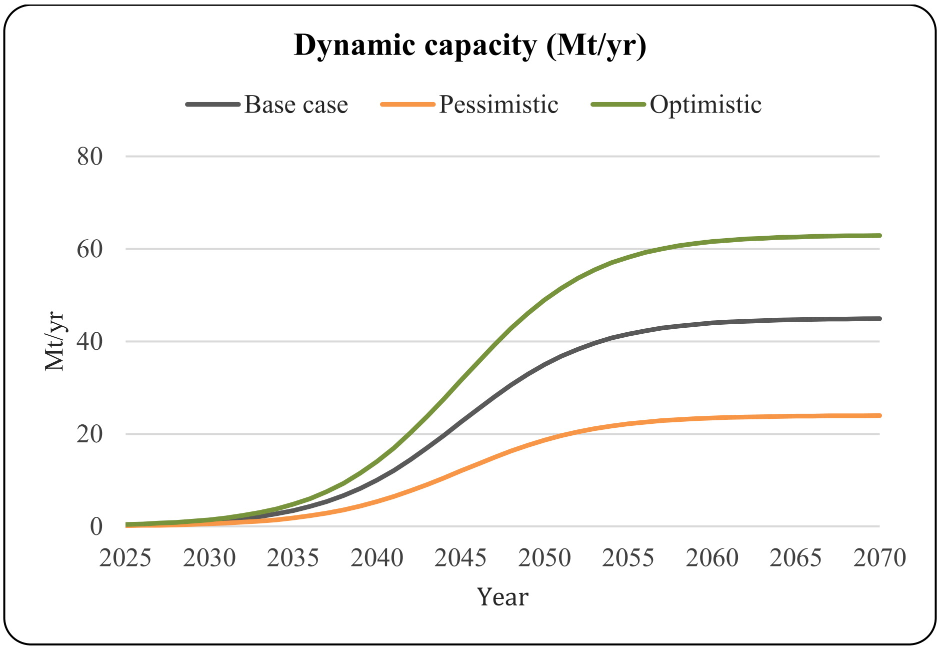

Figure 1 *Expected evolution of dynamic storage capacity in Indian sedimentary basins through 2070, based on existing injection rates and expected project development timelines.*

Figure 1 shows the dynamic capacity profile developed for India's storage portfolio in saline aquifers. The S-curve shows negligible capacity available before 2030, rapid growth through the 2040s as pilot projects mature and infrastructure is built out, and a flattening from the mid-2050s onward as the most accessible sites are progressively exhausted. Under the base case, national dynamic capacity reaches approximately 45 Mt/yr by 2070, compared with roughly 24 Mt/yr in the pessimistic case and 63 Mt/yr in the optimistic case.

Spatial heterogeneity in storage readiness is also a significant . Cambay, Mumbai Offshore and Rajasthan basins are expected to lead early development between 2025 and 2035, given their existing hydrocarbon infrastructure and ongoing feasibility studies, including the Gandhar field pilot project [Vishal et al., 2025]. Krishna-Godavari and Cauvery basins, which hold significant capacity but have no dedicated storage studies underway yet, are expected to follow between 2035 and 2050, supported by nearby emission clusters of around 72 Mt-CO_2/yr and 65 Mt-CO_2/yr respectively. Category II and III basins including Kutch, Saurashtra, Vindhyan, Mahanadi and Bengal are likely to require further characterisation investment before 2050 if they are to contribute meaningfully to storage capacity in the following two decades.

Conclusions

This study provides updated estimates of effective CO_2 storage capacity in India's saline aquifers, combining reservoir simulation derived efficiency factors with a temporal deployment profile that has not previously been available at this level of detail. The base case capacity of 193.9 Gt confirms that saline aquifers remain the dominant storage resource for India's net zero pathway, but the dynamic analysis makes clear that only a small fraction of this resource will be practically accessible before the mid-2030s. Aligning the pace of storage site characterisation, particularly in Category II basins with strong nearby point source clusters, with the projected ramp up in CCUS deployment will be important if storage availability is not to become a bottleneck for India's broader decarbonisation timeline.

Acknowledgement

This work was carried out at the National Centre of Excellence in Carbon Capture, Utilisation and Storage, IIT Bombay, as part of a study commissioned to support Net-Zero India integrated assessment modelling framework, undertaken jointly with IIT Delhi. The authors thank ONGC and the Directorate General of Hydrocarbons for access to subsurface and reserves data that informed this assessment.

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