Basin-Scale Mapping and Screening of CO_2 Storage Sites in the Cambay Basin, India

Introduction

Carbon capture, utilisation, and storage (CCUS) is a critical, large-scale strategy for mitigating climate change, largely driven by greenhouse gas emissions, particularly the 75% originating from fossil-fuel combustion, as mentioned in the IEA (2021). While many nations target net-zero emissions by mid-century, India has set a net-zero goal for 2070 (Vaughan, 2021), balancing its developmental and energy needs with its climate commitments. Renewable energy will help in reducing the carbon intensity of power generation. However, India's growing economy needs the expansion of power-intensive industries, which means that the usage of fossil fuels will remain partly unavoidable. As a result, renewable sources cannot fully decarbonise, especially in the hard-to-abate sectors such as cement, steel, and refining. Geological CO_2 storage (GCS) is an essential complement to renewable-based strategies. Global examples from large-scale carbon capture and storage (CCS) projects such as Sleipner, Weyburn–Midale, and Quest have proven that CO_2 can be safely and long-term stored in deep saline aquifers and depleted oil and gas fields. GCS offers a great mitigation potential in India. Accordingly, the Indian government has allocated US$2.2 billion in the 2026–27 budget to advance CCUS. India's 26 sedimentary basins, featuring thick reservoirs, effective seals, and extensive subsurface data, provide strong potential for large-scale CO_2 storage.

Cambay Basin: A Promising CO_2 Storage Basin

The onshore Cambay Basin of western India is one of the country's most mature hydrocarbon-producing basins and has been identified as a highly prospective region for GCS (Vishal et al., 2021; Williams et al., 2025). It has favourable geological characteristics, extensive availability of subsurface data, and proximity to major emission sources. Decades of hydrocarbon exploration and production have generated a dense network of wells and seismic datasets, significantly reducing subsurface uncertainty. The basin hosts multiple sandstone reservoirs interbedded with regionally extensive marine shale units that have retained hydrocarbons over geological timescales, demonstrating effective natural containment. These characteristics provide strong potential for CO_2 storage in both depleted reservoirs and associated saline aquifers. Collectively, these attributes position the Cambay Basin as a strong candidate for large-scale CO^2 storage development in India.

Stratigraphy and Storage Systems in Cambay

The Cambay Basin in western India, a north-south trending intracratonic rift basin, is a promising area for GCS. This is due to its substantial Cenozoic sedimentary layers, deposited over Deccan Trap basalts. Specifically, the Palaeocene–Eocene post-rift sediments have formed a stacked reservoir–seal pairs ideal for developing CO_2 storage systems.

The primary CO_2 storage system occurs within the Middle Eocene Kalol Formation and its equivalents. The reservoir units consist of deltaic to shallow-marine sandstones, which are sealed by marine shales belonging to the upper members of the formation, providing favourable conditions for long-term containment.

Input Data

As part of the screening workflow, a comprehensive subsurface dataset covering the Cambay Basin was compiled and standardised. The dataset includes well log information from more than 3000 wells, over 20 regional 2D seismic lines, and 10 3D seismic surveys. All seismic and well data were quality-checked, loaded, and harmonised to a single coordinate reference system (WGS 84 / UTM Zone 43N) for spatial consistency and reliable integration. Representative wells were shortlisted based on spatial distribution, depth, available key logs (gamma-ray, sonic, and density), and quality to provide stratigraphic control for regional mapping and correlation of CO_2 storage relevant reservoir and seal units. Sonic calibration with VSP data minimised depth-time uncertainty. Seismic-to-well ties were generated using synthetic seismograms derived from calibrated sonic and density logs and matched to corresponding seismic traces. Through integrated interpretation of seismic and well data, regionally correlatable horizons were identified and mapped across the Cambay Basin. Priority was given to formations displaying laterally continuous seismic reflectors regionally, proven reservoir-quality sand bodies, and overlying shale intervals capable of providing effective seals. The final mapped surfaces include Kand Fm Top, Babaguru Fm Top, Tarapur Shale Top, Kalol Formation and its equivalent, Cambay Shale Top, Olpad Fm Top and Deccan Trap Top (Economic Basement).

Methodology

The screening and scoring methodology utilises different criteria relevant to reservoir storage capacity, storage containment, and socio-economic concerns. Reservoir depth and thickness are the primary criteria for storage capacity, fault distance for storage containment, and proximity to population centres, which relate to socio-economic concerns. The reservoir's distance to faults and population centres is used as a screening criterion. These areas' proximity to these criteria is considered a high-risk, thus excluded from scoring. The screened regions are then evaluated using defined parameter ranges for each criterion. Based on these ranges, each area is graded as Poor, Marginal, Adequate, Good, or Excellent, with scores ranging from 0.5 to 1. The detailed scoring scheme is provided in Table 1. The scores from each criterion are multiplied together to calculate a final suitability score between 0.25 and 1 for each region across the Cambay Basin.

Table 1 *The criteria and parameters for screening and scoring regions in the Cambay Basin for CO_2 storage.*

Criteria	**Screening parameter**	**Scoring parameters**				
		Poor	***Marginal***	***Adequate***	***Good***	***Excellent***
Depth to top of the reservoir (m)	1000	1000-1250	>3000	2250-3000	1250-1750	1750-2250
Reservoir thickness (m)	10	10-20	20-30	30-40	40-50	> 50
Distance from population centre (km)	5	-				
Distance from fault (km)	1	-				
Score	**0**	**0.5**	**0.6**	**0.75**	**0.9**	**1**

This initial screening of the Cambay Basin for suitable CO_2 storage reservoirs uses a limited set of criteria. This approach is necessary because detailed information is not available for every field across the basin; therefore, additional criteria would result in the exclusion of vast areas due to data limitations. Thus, this study is intended as a first-order screening, which can then guide more detailed characterisation efforts in the identified regions.

Results & Discussion

The Combined Chance of Success map (CCSM) in Figure 1 includes reservoir depth and the sand thickness maps of the Kalol Formation Top, overlained with the screening criteria, as discussed above. The combined evaluation enables the identification of zones that meet structural, stratigraphic, and socio-environmental screening criteria for CO_2 injection. The results are discussed below in terms of the proposed scoring parameters.

1. *Optimum Reservoir Depth*

The depth considered for the favourable storage interval lies between 1250 m and 2250 m. Within this range, reservoir conditions are expected to maintain CO_2 in a dense, supercritical state, thereby improving storage efficiency and containment. Shallower intervals (<1250 m) are less suitable due to lower pressure–temperature conditions and potential regulatory constraints, whereas deeper zones (>2250 m) may entail higher drilling and operational costs. The mapped favourable zones within the adequate-to-excellent depth window constitute potential candidates for subsequent detailed evaluation.

2. Net Sand Distribution and its Thickness

The net reservoir thickness map reveals significant heterogeneity across the block, generated using a 50% cut-off from the gross sand thickness. For scoring potential CO_2 storage areas, the highest suitability scores are assigned to zones with a net sand thickness between 30 m and >50 m, as evaluated from well data. These intervals are considered optimal because they offer better lateral continuity of the sand bodies.

Specifically, zones exceeding 50 m in thickness receive the maximum weight in the scoring scheme, as they represent the best combination of storage capacity and injectivity potential. Conversely, thinner intervals (<30 m) are rated as marginal to poorly suitable due to their reduced sand thickness.

3. Distance from Population Centres

Socio-environmental screening indicates that proposed injection locations must be at least 15 km from major population centres. This buffer ensures risk mitigation in the unlikely event of leakage and aligns with safe operational planning principles. Consequently, areas within the highly urbanised zone will be excluded from the CCSM.

4. Fault Zone Buffering

To mitigate the risk of vertical and horizontal CO_2 migration across the fault zone, the screening model incorporates a minimum 1 km buffer on both sides of mapped fault traces. Areas within this fault influence zone are consequently screened out. In contrast, structurally stable compartments located outside the 1 km buffer are considered to have greater confidence in containment. Further analysis, however, is necessary and will be conducted through detailed site characterisation methods.

Conclusions

The current site-screening work represents a pioneering effort in the Indian context. Through this study, a basin-scale Combined Chance of Success Map has been prepared, which delineates approximately 4000 km² of low-risk storage area. It is based on a meticulous analysis of high-resolution subsurface data, enabling the identification and characterisation of specific geological formations for long-term, safe CO_2 containment.

The alignment of favourable reservoir properties, existing pipeline infrastructure, and proximity to CO_2 sources positions the Cambay Basin as an ideal site for India’s first pilot-scale CO_2 storage project. This initiative in India will generate critical operational experience, support the development of regulatory frameworks, and build public confidence, enabling the future scale-up of commercial CCS deployment nationwide.

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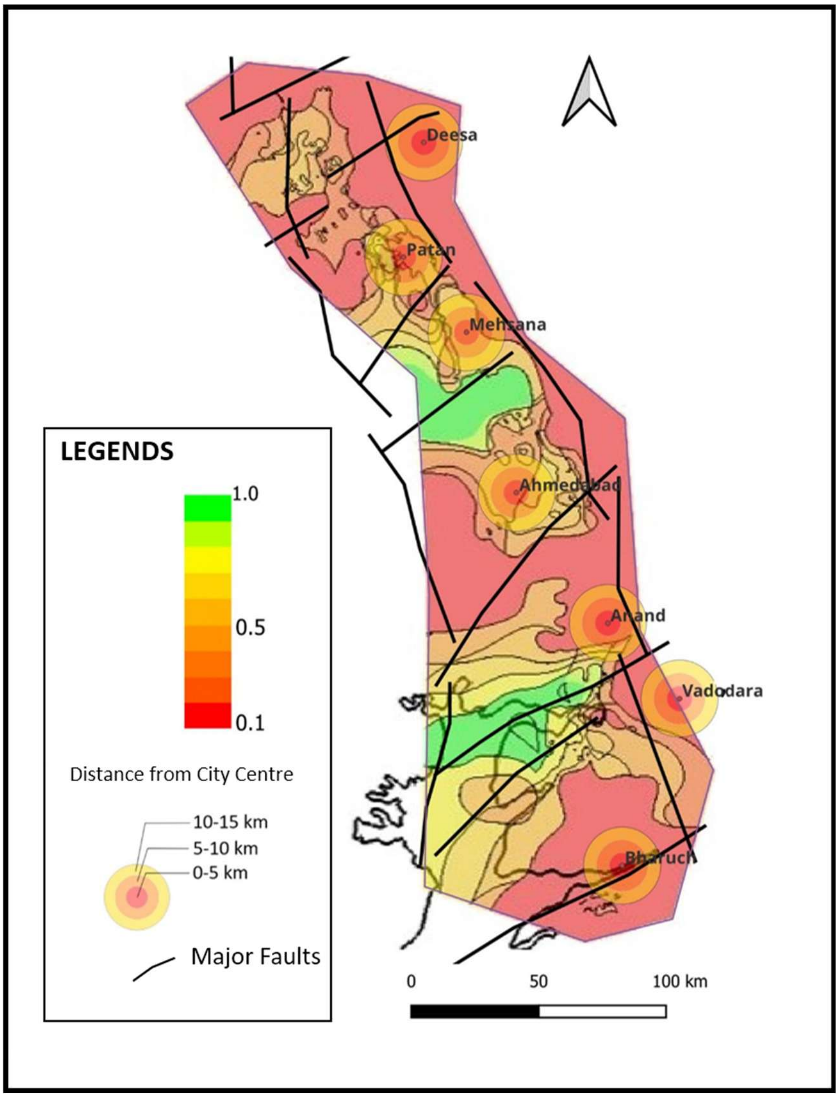

Figure 1 *The Combined Chance of Success Map of the Cambay Basin. The colours on the map indicate the normalised score from the integrated depth and reservoir thickness map. The lighter colours (green and yellow) show optimum depth and optimum thickness, whereas brighter colours (red and orange) show risk areas. The urbanised zones are shown in concentric circles. Beyond the 15 km zone, the risk to the population is minimal.*

References

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