Evaluating CCS readiness in India: CO_2 storage potential, source-sink mapping and policy outlook

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Abstract

The Government of India announced its commitment to reach net-zero greenhouse gas emissions by 2070 at the recent COP 26 summit. Modeling projections suggest that meeting this target would likely require substantial amounts of CO_2 capture and storage (CCS) from large-point sources (LPS). Our analysis first reveals the key co-benefits for India in the adoption of CCS, viz. energy security, lower aggregate costs of carbon mitigation, higher resilience and lower stranded assets. For instance, we estimate that stranding of >100 GW and >70 GW of coal- and gas-fired power capacity could be avoided with the presence of CCS in the power sector mix.

This analysis is further supplemented by our recent estimates on CO_2 storage potential estimates in Indian geologic formations. Our results indicate that the storage capacity via enhanced oil recovery (EOR) is 1.2 $GtCO_2$ after incorporating engineering and geologic constraints. Similarly, the storage capacity in unminable coal fields is estimated to be 3.5-6.3 $GtCO_2$. Even though the combined storage potential in these formations is constrained, they should be actively considered within policy-making as they predominantly lie within areas of dense areas of LPS, thus creating possibilities of CCS hubs and clusters. In addition, 291 $GtCO_2$ could be sequestered in saline aquifers and 97-316 $GtCO_2$ in basalts; though, these values are subject to higher uncertainties. A number of saline aquifers may be characterized as having storage potential equivalent to several years of LPS emissions (>10 $GtCO_2$) along with high storage feasibility.

Our ongoing analysis attempts a more evolved approach towards source-sink mapping in India by combining the storage potential estimates with geospatial layers of LPS. Large power plants, which emit >20 $MtCO_2$ annually, and high-purity CO_2 sources such as refineries, are of particular interest. Preliminary source-sink mapping results show substantial clustering opportunities in eastern India, which has active coalbed methane extraction undertaken by five companies, and western India, with large industrial sources interspersed with EOR sites. The results of this analysis will also inform decision-makers on future LPS siting opportunities if a policy thrust on CCS is undertaken for meeting net-zero targets over the next two decades.

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The Government of India announced its commitment to reach net-zero greenhouse gas emissions by 2070 at the recent COP 26 summit. Modeling projections suggest that meeting this target would likely require substantial amounts of CO_2 capture and storage (CCS) from large-point sources (LPS). Our analysis first reveals the key co-benefits for India in the adoption of CCS, viz. energy security, lower aggregate costs of carbon mitigation, higher resilience and lower stranded assets. For instance, we estimate that stranding of >100 GW and >70 GW of coal- and gas-fired power capacity could be avoided with the presence of CCS in the power sector mix.

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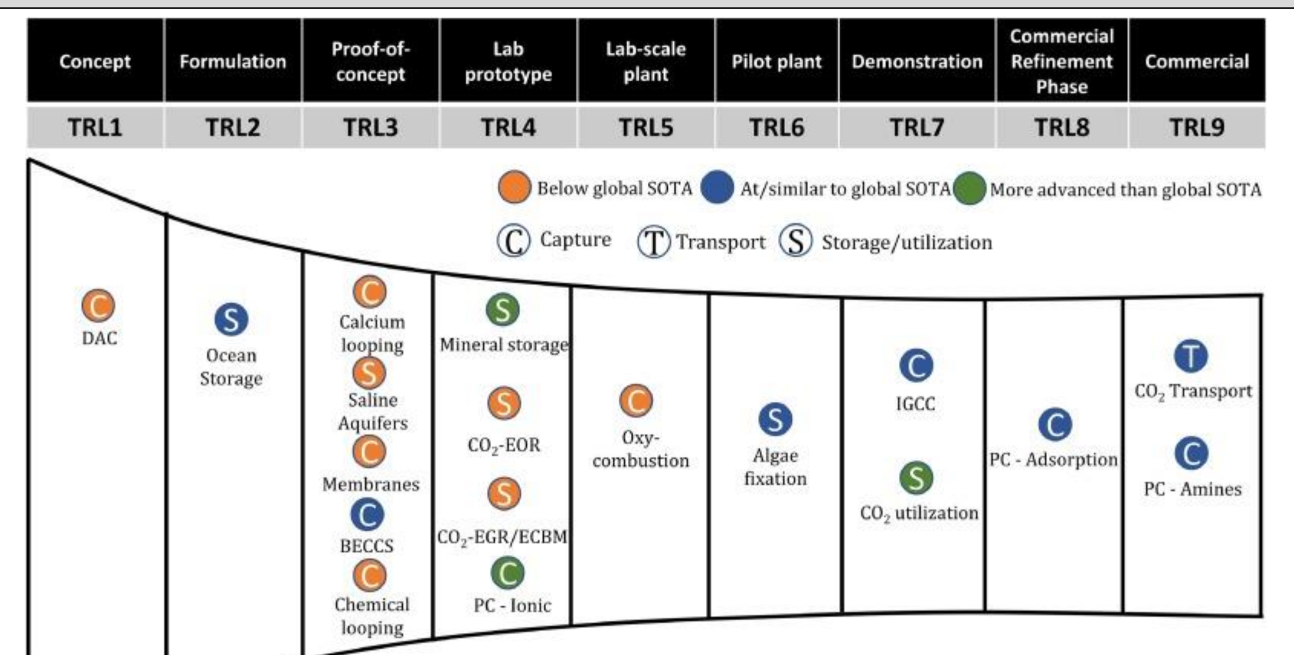
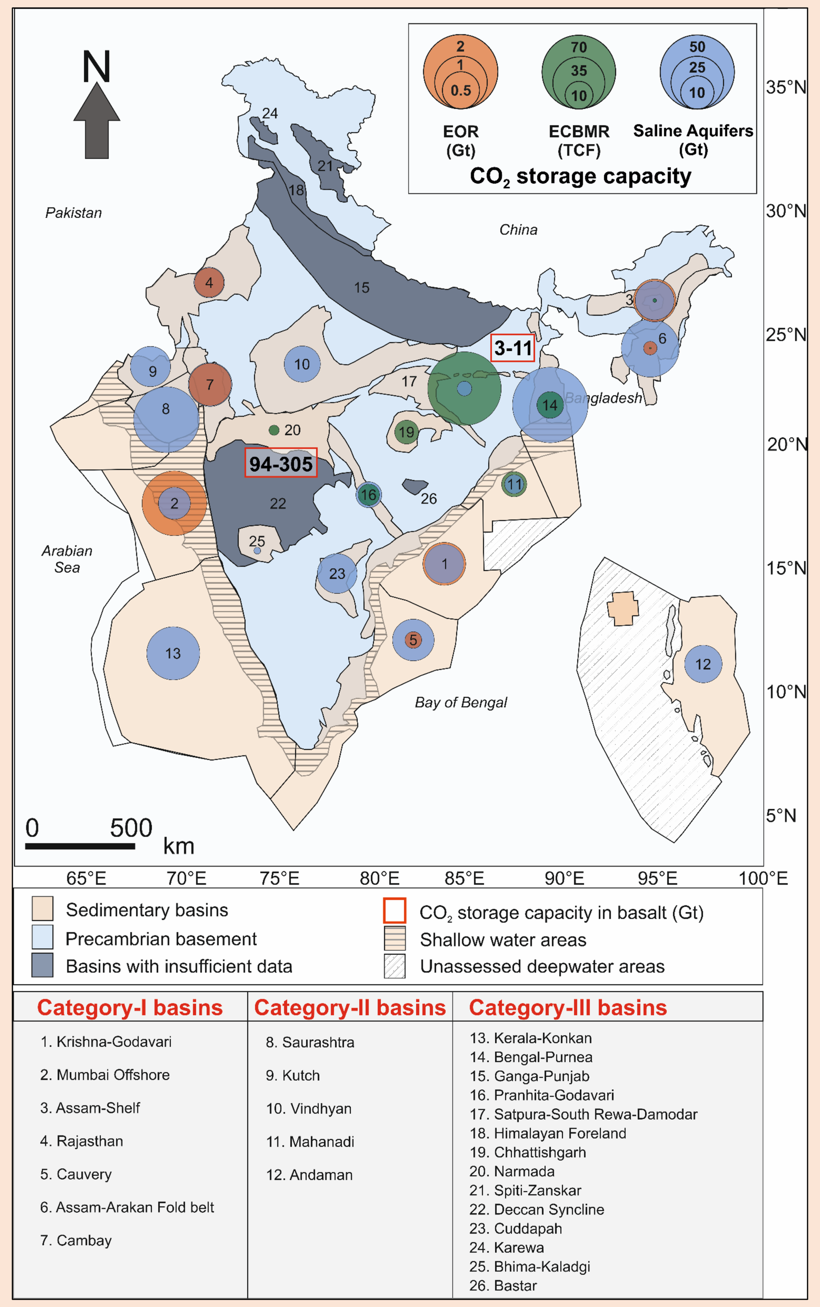
Technology Readiness Levels for India



TRL levels of different CCUS technologies available in India (Vishal et al., 2021b)

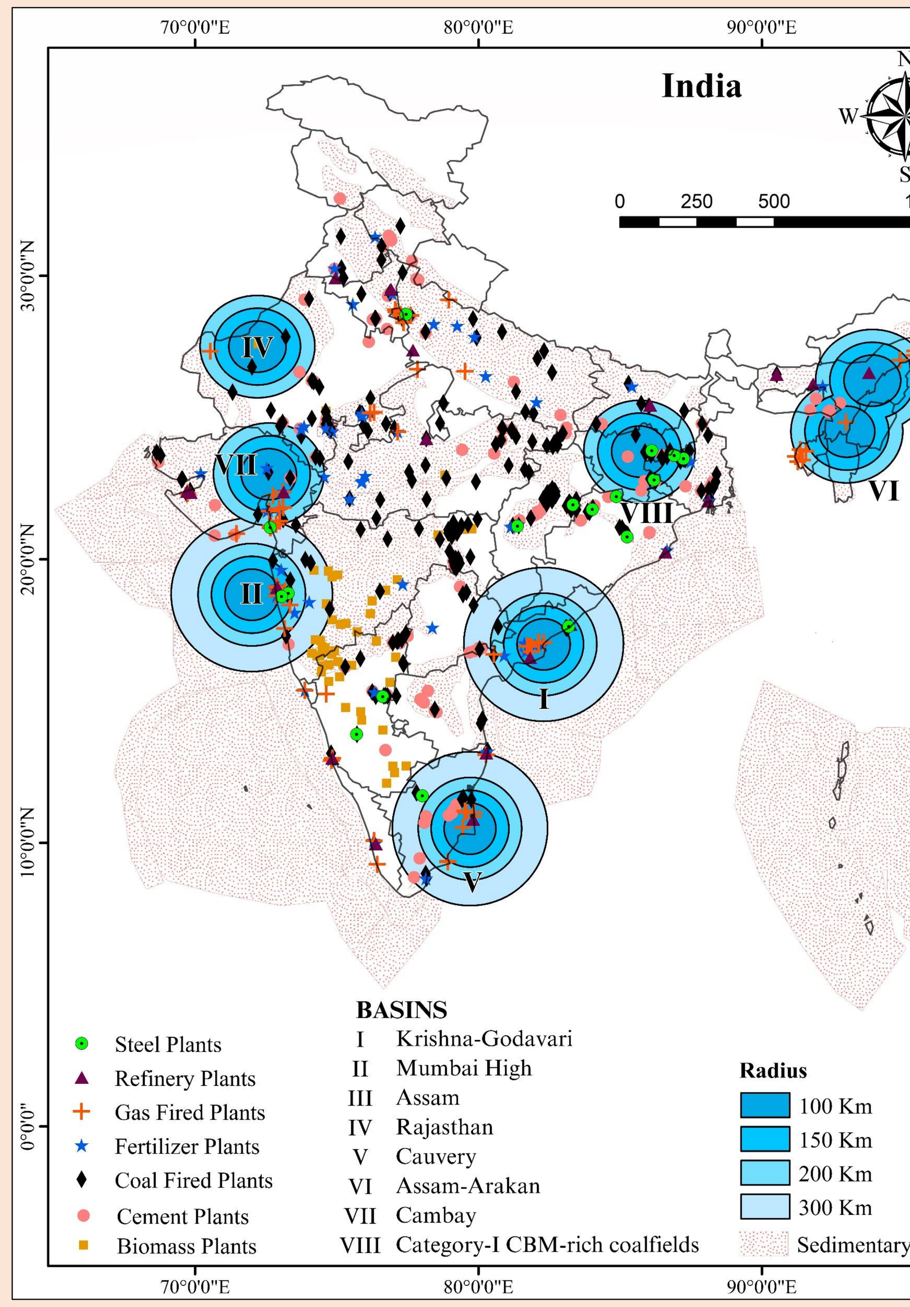
CO_2 storage potential



(Vishal et al., 2021a)

Major sedimentary basins in India, showing CO_2 storage potential through EOR, ECBMR, in saline aquifers, and basalt.

Source-sink mapping

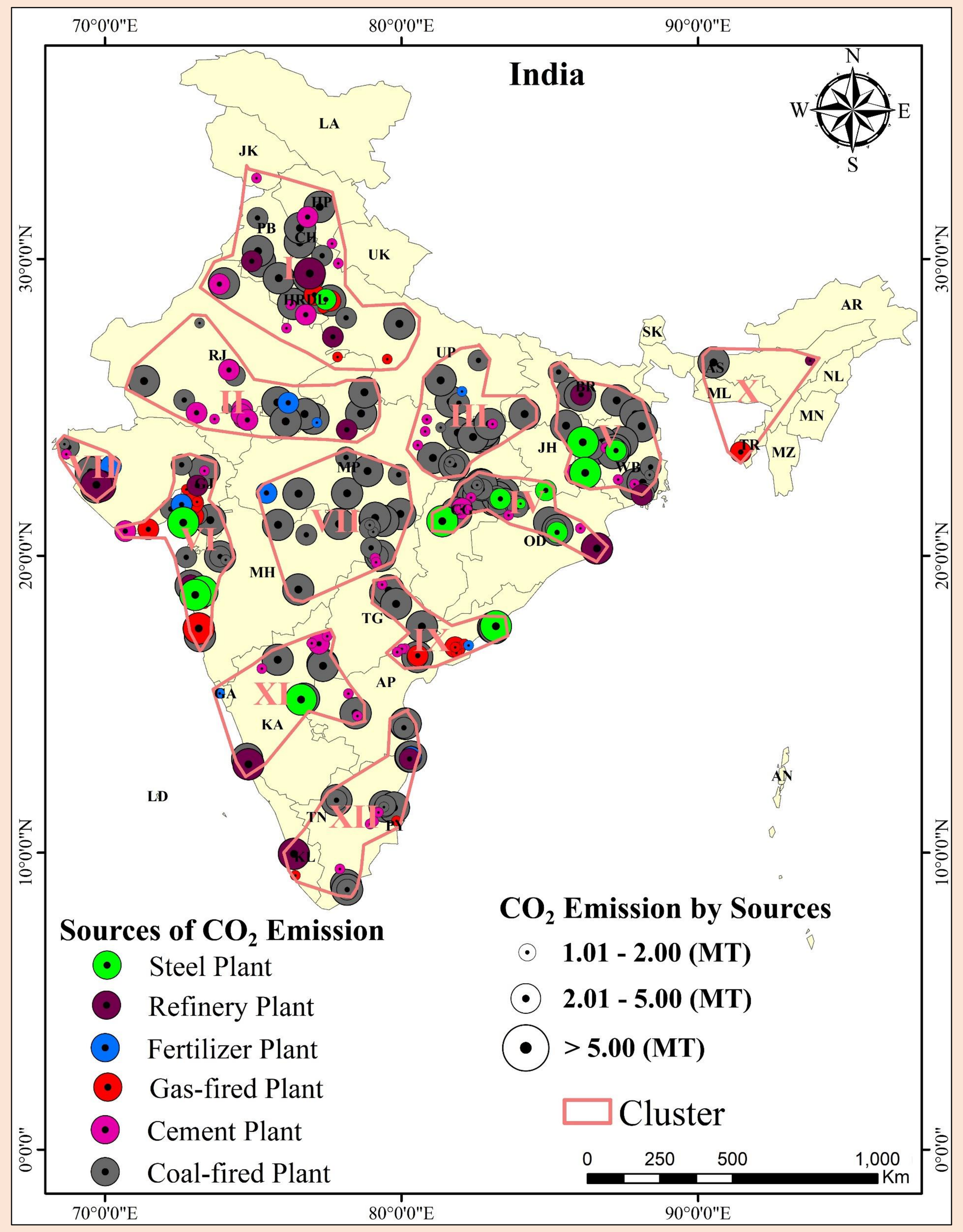


(Vishal et al., 2022)

Identified source-sink clusters for key sedimentary basins and coalfields in India.

The concentric circles represent radial distance from the Euclidian center of each sink.

Hubs-and-clusters network



(Vishal et al., 2022)

The proposed hubs and clusters for implementing CCS network across India. It is based on studies that the model is more economically viable when the sinks are involved in EOR or ECBM recovery.

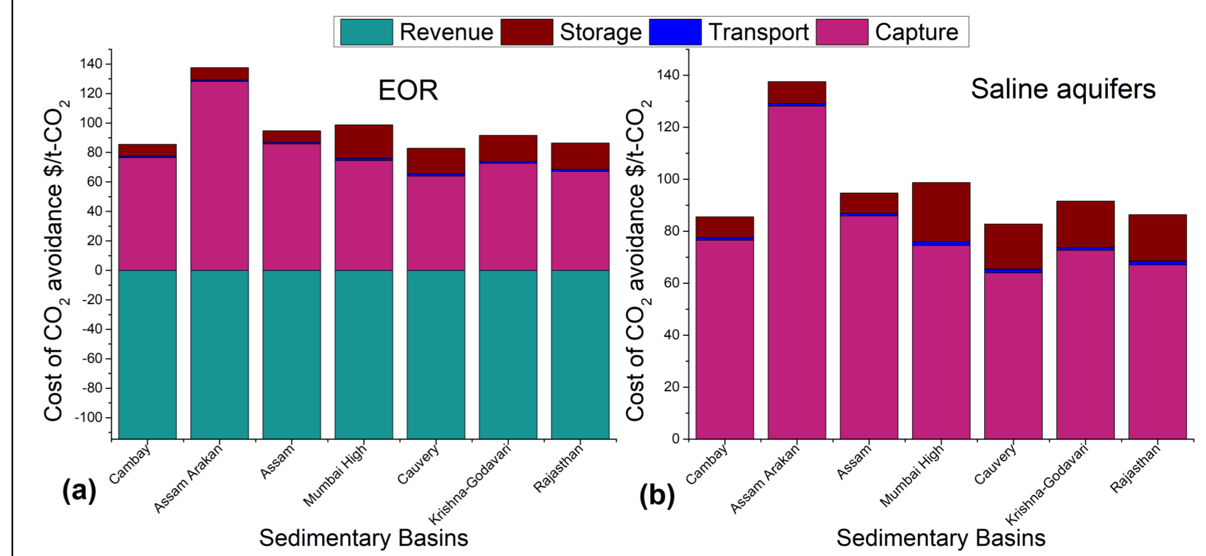
- Novel estimates indicate considerable potential for CO_2 storage in India, through **EOR (3.4 Gt), ECBMR (3.7 Gt),** and especially in **saline aquifers (291 Gt)** and **basalt (97–316 Gt)**.
- **Source-sink matching** using these estimates describes seven clusters in sedimentary basins (with and without EOR) and one cluster in the Damodar Valley coalfields in eastern India. These can potentially sequester over **400 Mt-CO_2/year,** corresponding to **12 $GtCO_2$** over a 30-year duration.
- First-order estimate of the costs of CCS in these clusters are estimated to be **\$87-107/t-CO_2 in saline aquifers, - \$31 to -\$15/t-CO_2 for EOR,** and **\$60/t-CO_2 for ECBMR**.

Source-sink analysis

Basin	Emissions (Mt-CO_2/year)	No. of LPS	Average distance of LPS to sink (km)	Emissions from power sector (%)	Percent of sequestration possible with additional resource recovery (%)	Storage potential needed for 30 years (Gt-CO_2)
Sedimentary basins (Category-I oil and gas basins)						
Mumbai High	81	33	160	49	65	2.43
Krishna-Godavari	72	27	114	78	30	2.16
Cauvery	65	25	148	85	5	1.95
Cambay	49	23	119	78	45	1.47
Rajasthan	12	6	125	93	88	0.36
Assam-Arakan	2.0	6	102	22	100	0.06
Assam	1.7	2	82	38	100	0.05
Coalfields (Category-I CBM basins)						
Damodar Valley	120	29	116	71	39	3.60

Summary of CCS clusters based on matching large point sources and sinks, including EOR basins, saline aquifers, and coal fields.

Cost of CO_2 avoidance



Overall system cost of avoidance for sedimentary basins for storage in (a) EOR reservoirs and (b) saline aquifers

POLICY OUTLOOK

- Meeting India's targets towards climate change would likely require continued carbon management initiatives by the government and financial aid for participating industries.
- Urgent need for an integrated policy framework for CCUS in India. The anticipated levels of CCUS deployment would require a coordinated policymaking across sectors and bring in economic benefits of \$10-20/tCO_2 due to economies of scale.
- It would also facilitate operation of infrastructure such as CO_2 pipelines as well as institutional measures such as life-cycle scrutiny.

CONCLUSION

The overall cost for CCS in saline aquifers in India is substantially higher than global averages. Financial revenues from EOR and ECBMR are necessary to jumpstart CCS in India. A robust policy framework is also needed to advance CCUS infrastructure.

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