Accelerating CCUS Deployment in the Global Cement Sector - India focus

A collaboration between:
- Global Cement and Concrete Association
- Global CCS Institute
- Clean Energy Ministerial CCUS Initiative
- Global CCS Foundation

Agenda

- Welcome and Introduction
- Opening remarks by the partners
  - CEM CCUS, Abdullah Ameer
  - GCCSI, Bernardene Smith
  - GCCA, Thomas Guillot
- Current Status of the Indian Cement Industry – Kaustubh Phadke, GCCA India
- CO_2 Storage resources in India – Mojtaba Seyyedi, GCCSI
- Matching capture in cement with storage in India – Jerrad Thomas, GCCSI
- CCUS initiatives and activities in India – Vikram Vishal, IIT Bombay
- Overall summary, conclusions and next steps
- Close

Global Cement and Concrete Association

CARBON CAPTURE, UTILIZATION & STORAGE
ACCELERATING CCUS TOGETHER
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

GLOBAL CCS FOUNDATION

GLOBAL CCS INSTITUTE

GCCA – GCCSI – CEM CCUS collaboration on decarbonisation of India's cement industry 2023-2024

Study outcomes

Outcome 1
Identify potential CCUS hub locations

Outcome 2
Define policy and financing frameworks for bankable projects

Outcome 3
Identify 'first mover' CCUS pilot projects

Outcome 4
Awareness and capacity building

Study activities

Outcome 1	Outcome 2	Outcome 3	Outcome 4
• A general overview of the role of CCUS for cement decarbonisation • Deep-dive into potential cement-CCUS hubs in India • Create buy in of industry leaders and regulator • Determine economic value of potential hubs	• Assess existing regulatory context for CCUS in India • Perform gap analysis against existing frameworks in other jurisdictions • Develop appropriate business models for cement/CCUS hubs • Identify funding opportunities	• Identify 2-3 potential leading projects from pipeline • Perform high-level capture technology review • Perform conceptual design studies • Support feasibility studies for first mover projects • Produce development plans where feasible	• Raise awareness throughout cement sector and build capacity on role of CCUS to decarbonise cement • Report out at CEM-15 in Brazil • Potential next country to work on – Brazil

CARBON CAPTURE, UTILIZATION & STORAGE
ACCELERATING CCUS TOGETHER
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

GLOBAL CCS INSTITUTE

Global Cement and Concrete Association

GLOBAL CCS FOUNDATION

Abdullah Ameer

CEM CCUS

The Clean Energy Ministerial CCUS Initiative (CEM CCUS)

CEM15 MI-9
FOZ DO IGUAÇU BRASIL · 2024

Lead countries

Norway
Saudi Arabia
United Kingdom
United States

Participating CEM Members

Australia
Canada
China
EU Commission
Germany
Japan
Mexico
Netherlands
Nigeria
South Africa
United Arab Emirates

WHO WE ARE

CEM CCUS is a globally active government platform to accelerate CCUS deployment policy.

We have fifteen Member Countries from across the world, with close working links with

- Industry: GCCA, OGCI
- Finance Sector: various financial institutions
- Thought leaders: GCCSI, IEA, IEAGHG etc.

We advance carbon management by

- Elevating CCUS in minister-level discussions
- Working with industry and the finance sector to identify investment and CCUS growth opportunities
- Sharing knowledge on best practice CCUS strategy and policy among members and with the wider carbon management community.

gcca Global Cement and Concrete Association

CO_2 CARBON CAPTURE, UTILIZATION & STORAGE
ACCELERATING CCUS TOGETHER
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

GLOBAL CCS FOUNDATION

GLOBAL CCS INSTITUTE

Bernardene Smith

GCCSI

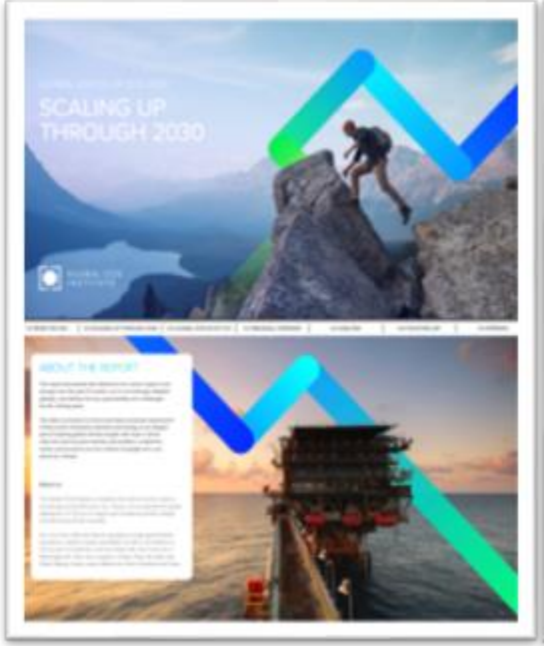
THE GLOBAL CCS INSTITUTE - Accelerating the deployment of CCS for a net-zero emissions future

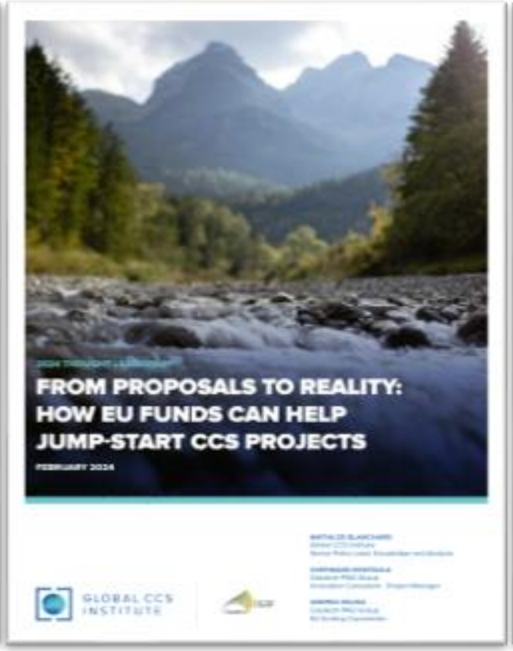
WHO WE ARE

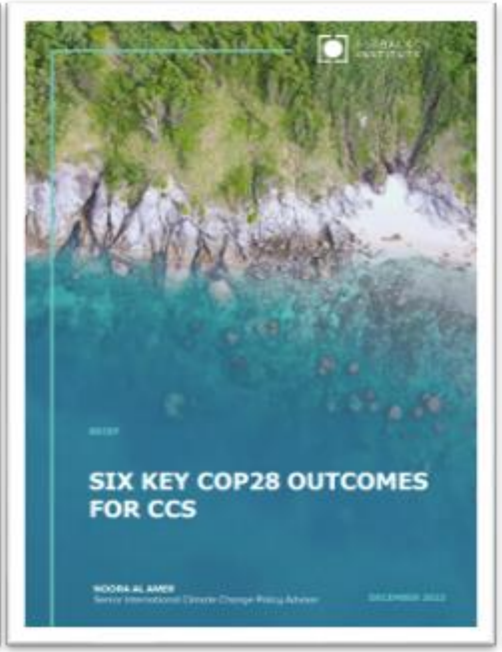
- International, non-profit climate change think tank
- Headquarters in Melbourne and offices in Washington D.C., Houston, London, Brussels, Abu Dhabi, Beijing, and Tokyo
- More than 200 members comprising governments, global corporations, technology companies, research institutions, and non-governmental organisations

WHAT WE DO

- Fact-based CCS advocacy
- Catalytic thought leadership
- Authoritative knowledge-sharing







Global Cement and Concrete Association

CARBON CAPTURE, UTILIZATION & STORAGE
ACCELERATING CCUS TOGETHER
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

GLOBAL CCS FOUNDATION

GLOBAL CCS INSTITUTE

Thomas Guillot

GCCA

10 new members in the last 12 months

GCCA is an attractive organization

80%

GCCA members account for 80% of the global cement industry volume outside of China - and include several leading Chinese manufacturers.

Our Members

- Asia Cement Corporation
- Breedon Group
- **BUA Cement***
- Buzzi
- Cementir Holding
- Cementos Argos
- Cementos Moctezuma
- Cementos Pacasmayo
- Cementos Progreso
- CEMEX
- **Cimenterie Nationale***
- Çimsa Cimento
- CNBM
- CRH
- Dalmia Cement
- Dangote
- **Emirates Steel Arkan***
- Fletcher Building
- GCC
- Heidelberg Materials
- Holcim
- **Hima Cement***
- **Huaxin Cement***
- JK Cement
- JSW Cement
- Medcem
- Misr Cement Group
- Molins
- Nesher Israel Cement Enterprises
- Norm Cement
- **Northern Region Cement Company***
- Orient Cement
- PT Solusi Bangun Indonesia
- SCHWENK Zement
- Secil
- Siam Cement Group
- Siam City Cement
- Taiheiyo Cement
- Taiwan Cement Corporation
- TITAN Cement Group
- **TPI Polene***
- UltraTech Cement
- UNACEM
- Vassiliko Cement
- Votorantim Cimentos
- YTL Cement
- **Yura Cement***

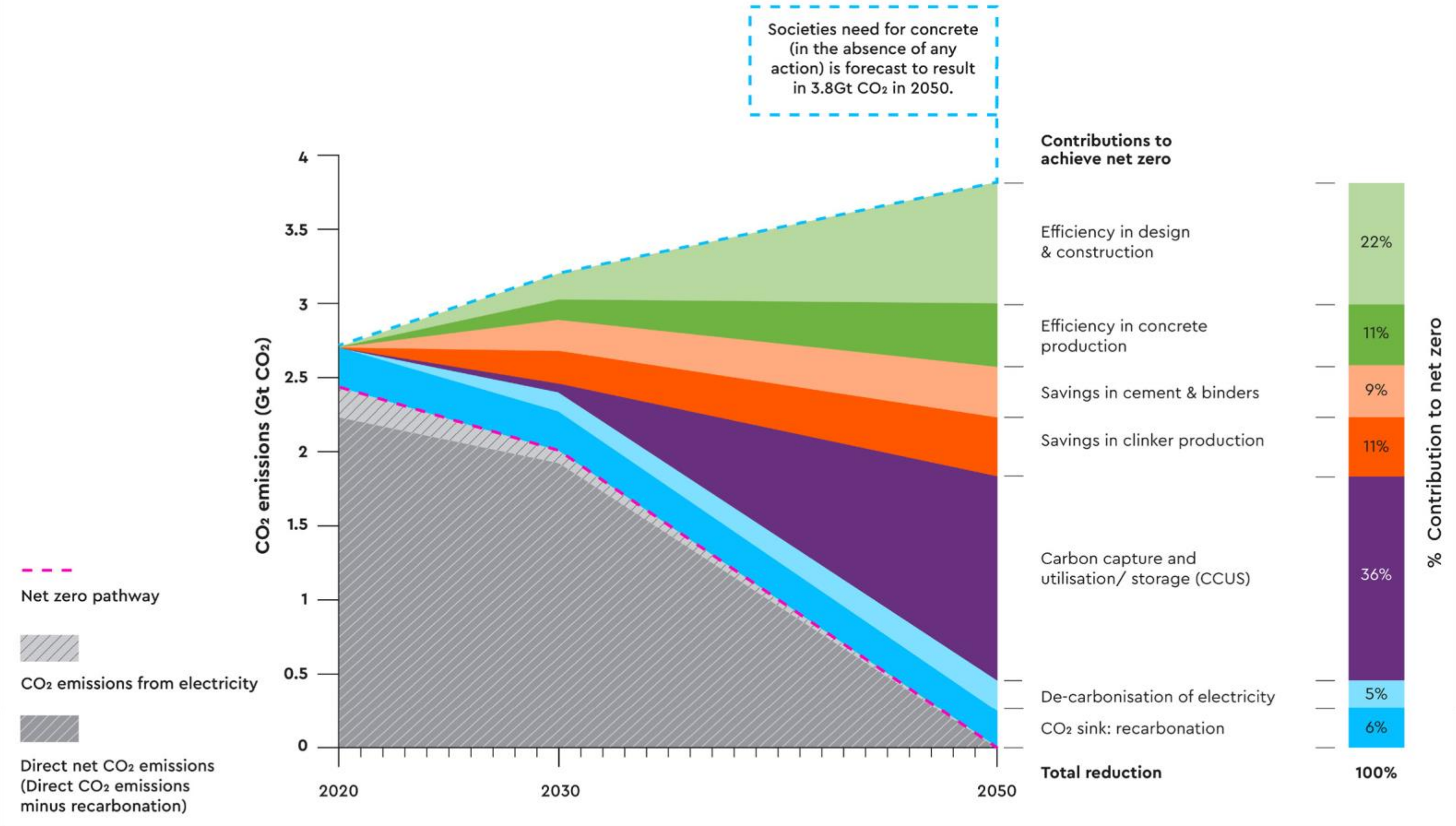
National & Regional Association Partners

- Asociación de Fabricantes de Cemento Portland – Argentina
- Asociación de Productores de Cemento – Peru
- Associação Brasileira de Cimento Portland – Brazil
- Association of German Cement Manufacturers (VDZ) – Germany
- Association Professionnelle des Cimentiers – Morocco
- Betonhuis – Netherlands
- BIBM – Europe
- CANACEM – Mexico
- Canadian Precast Prestressed Concrete Institute
- Cement Association of Canada
- Cement Concrete & Aggregates Australia
- Cement Industry Federation – Australia
- Cement Manufacturers Association – India
- Cement Manufacturers Ireland
- **China Cement Association***
- Concrete NZ – New Zealand
- European Cement Association (CEMBUREAU)
- European Federation Concrete Admixtures
- European Ready Mixed Concrete Organisation
- Federación Iberoamericana del Hormigón Premezclado – LatAm
- Federación Interamericana del Cemento (FICEM) – LatAm
- Japan Cement Association
- Korea Cement Association
- Mineral Products Association - United Kingdom
- National Ready Mixed Concrete Association – USA
- Portland Cement Association – USA
- **South India Cement Manufacturers Association***
- Thai Cement Manufacturers Association
- The Spanish Cement Association (Oficemen)
- Turkish Cement Manufacturers Association (TürkÇimento)

*** New Members and National & Regional Association Partners**

GCCA Net zero roadmap

Our sector response to global challenges

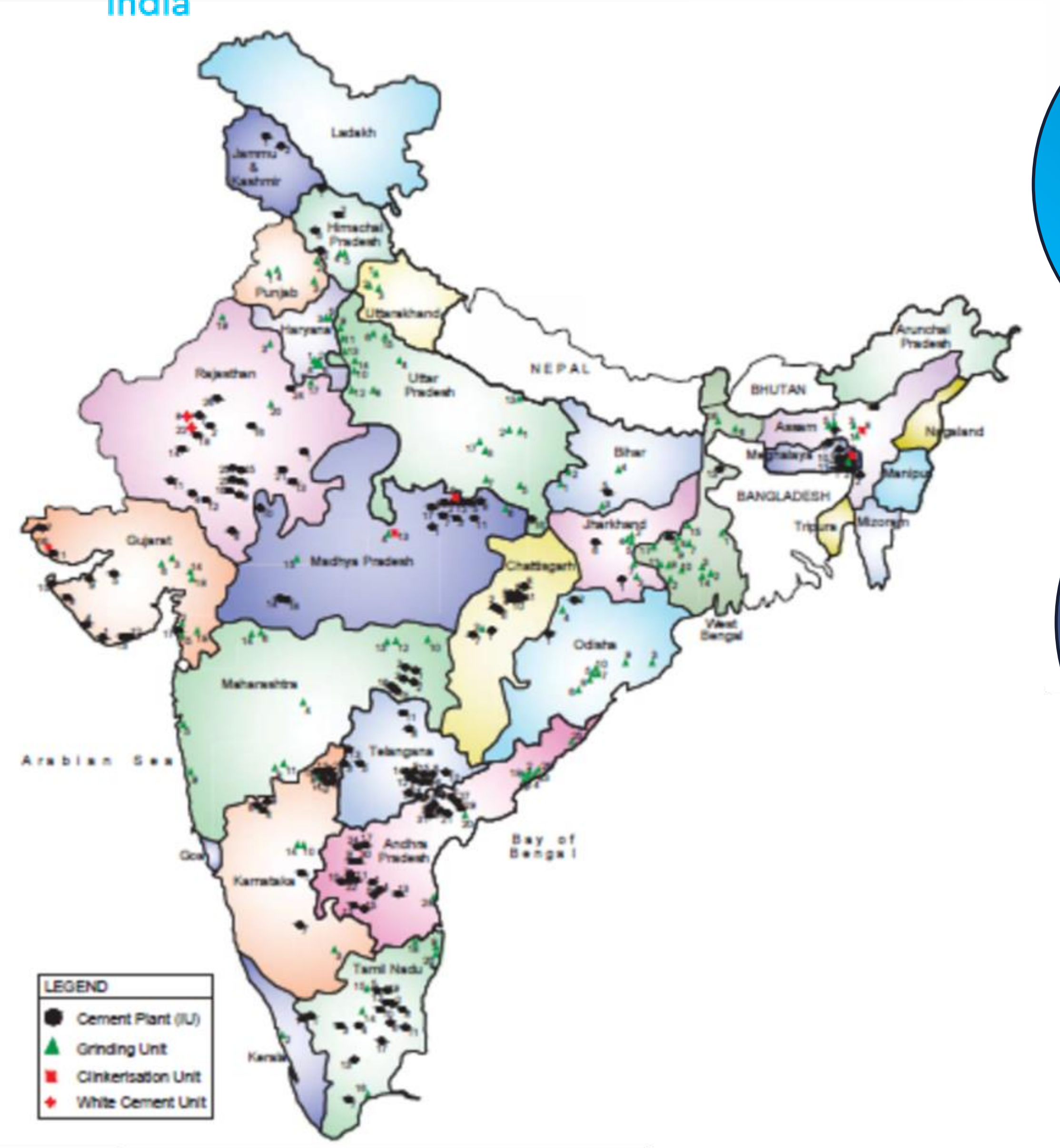


Kaustubh Phadke

GCCA India

Global Cement and Concrete Association
India

Overview of the Indian Cement Industry



2nd Largest Cement producer in the World

Installed capacity **594** million Tons (2021-22)

Cement Consumption of **260** kg per Capita

Employs more than million people directly or indirectly

333 Manufacturing Units

150 large integrated plants, **116** grinding units

1996	2010	2020
1.12	0.719	0.617
tCO2/tonne of cement	tCO2/tonne of cement	tCO2/ tonne of cement

Mojtaba Seyyedi

GCCSI

CCUS IN THE INDIAN CEMENT INDUSTRY- CO_2 STORAGE RESOURCES IN INDIA

Dr. Mojtaba Seyyedi
Global CCS Institute

OBJECTIVE

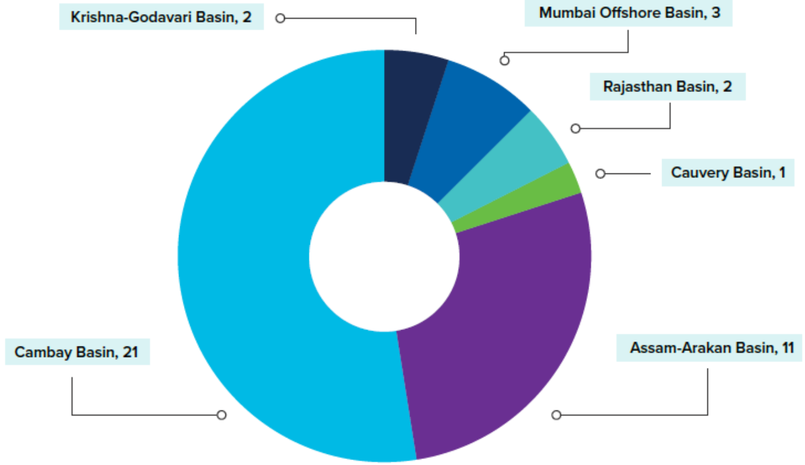
Estimating CO_2 storage resources in conventional oil and gas fields, saline formations, and basalts in India.

BASIN ASSESSMENT

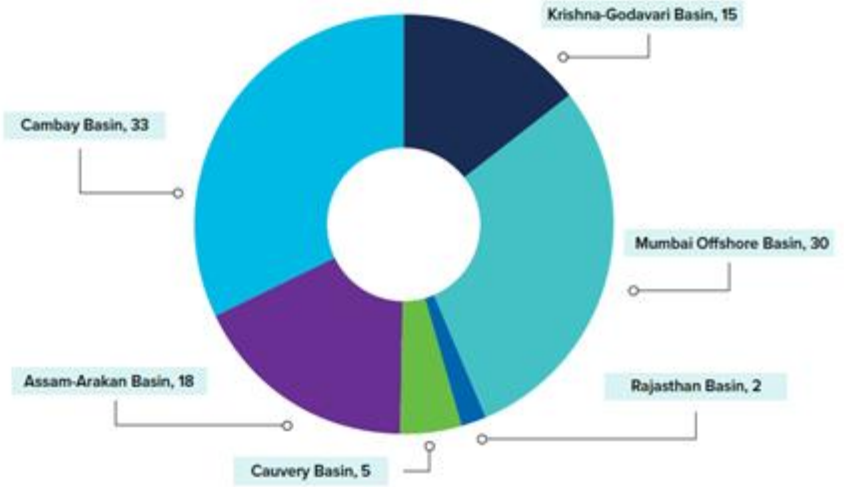
- **Category 1:** Basins with a well-established hydrocarbon exploration and production history.
- **Category 2:** Basins with contingent hydrocarbon resources pending commercial production (partially explored with no production history).
- **Category 3:** Basins that are largely unexplored and offer prospective resources awaiting discovery.

HYDROCARBON EXPLORATION AND PRODUCTION HISTORY

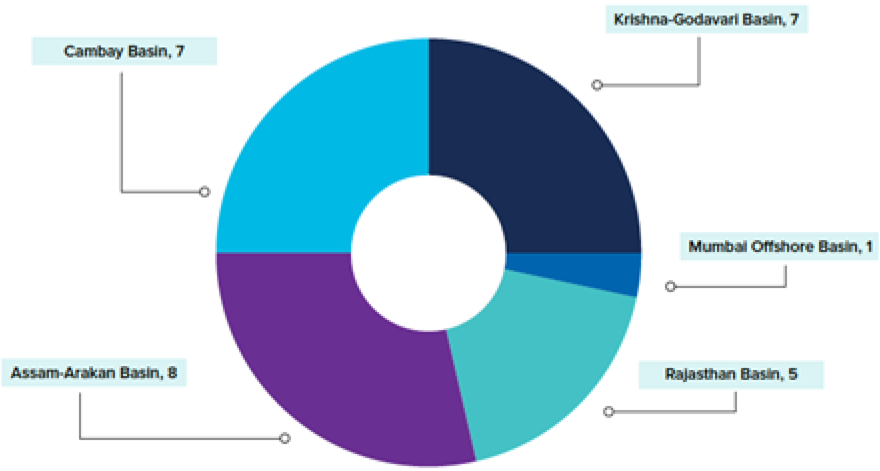
Producing conventional oil fields



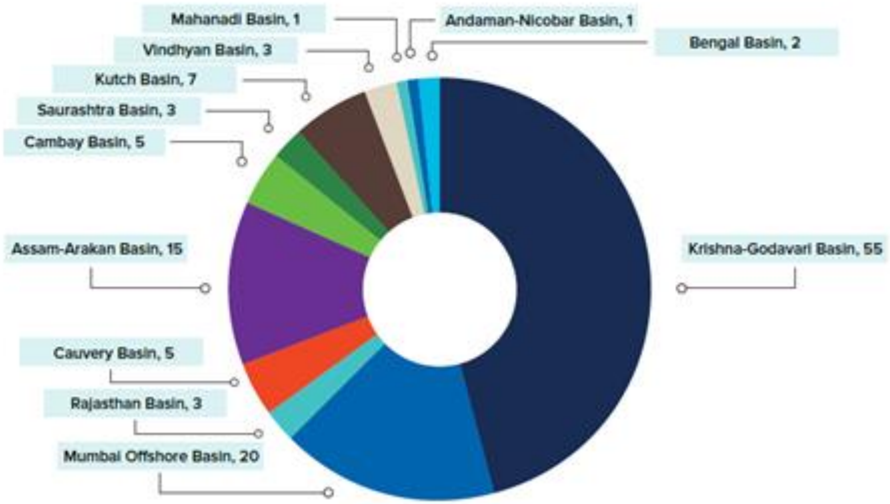
Discovered conventional oil fields



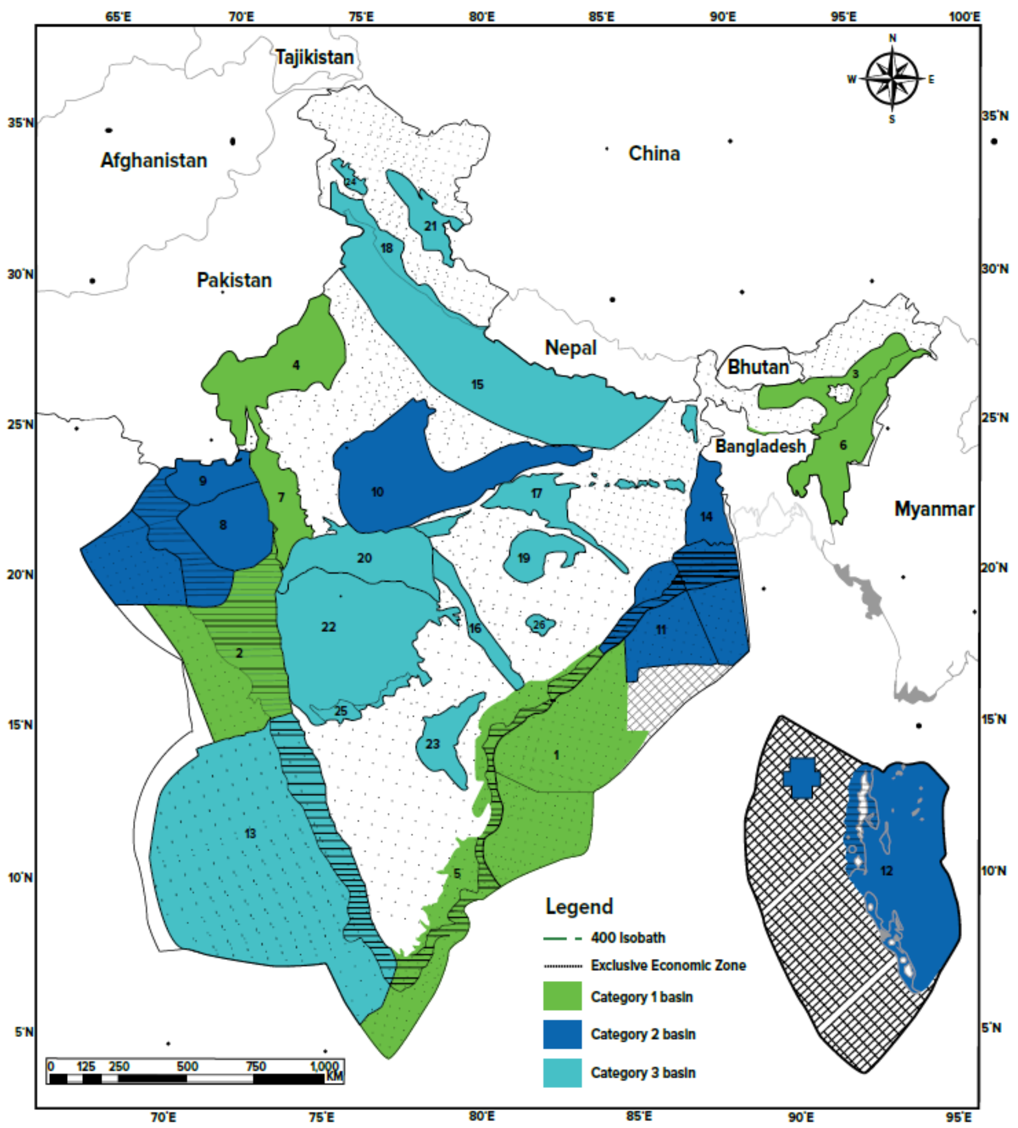
Producing conventional gas fields



Discovered conventional gas fields

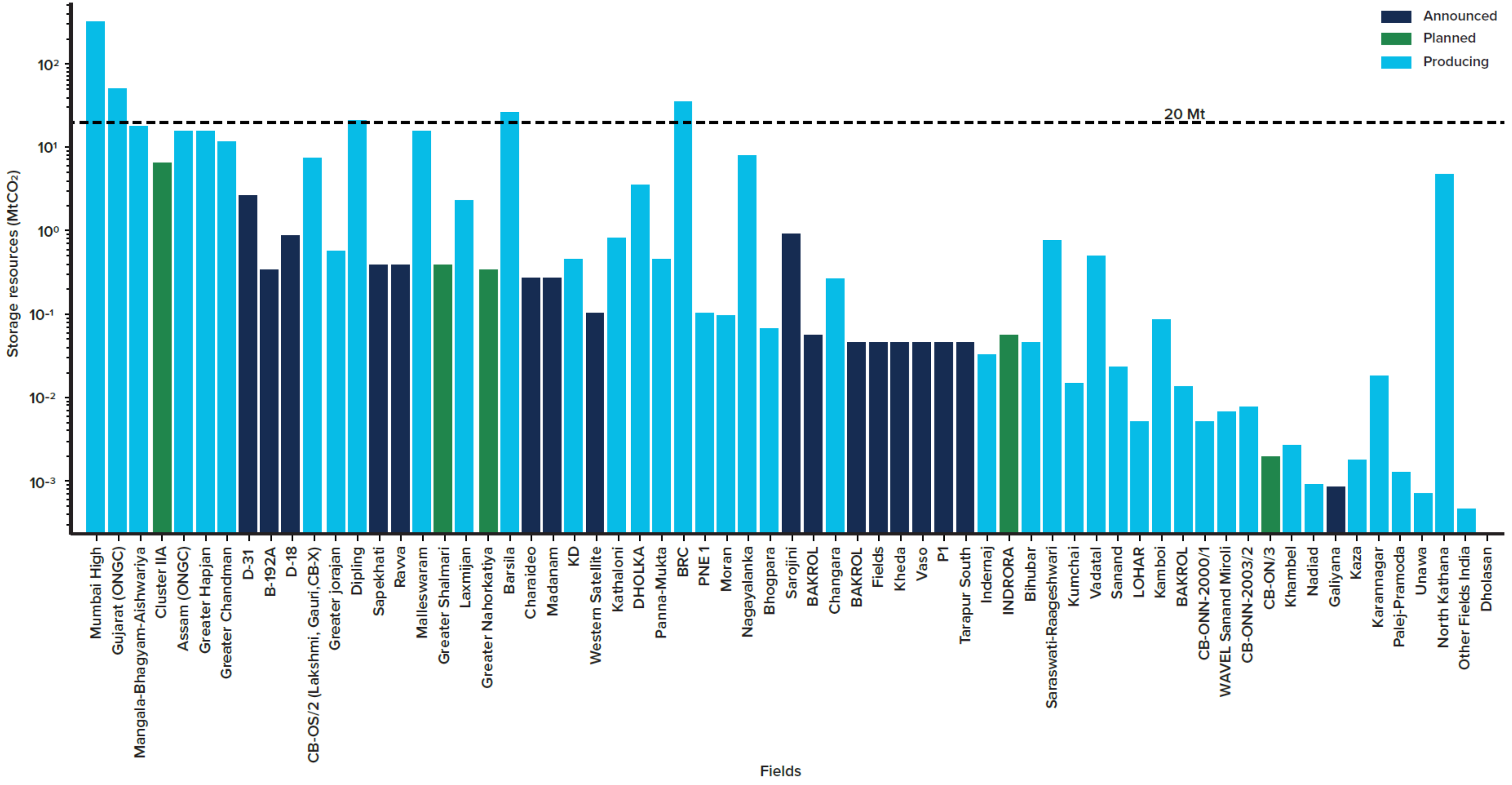


BASIN ASSESSMENT

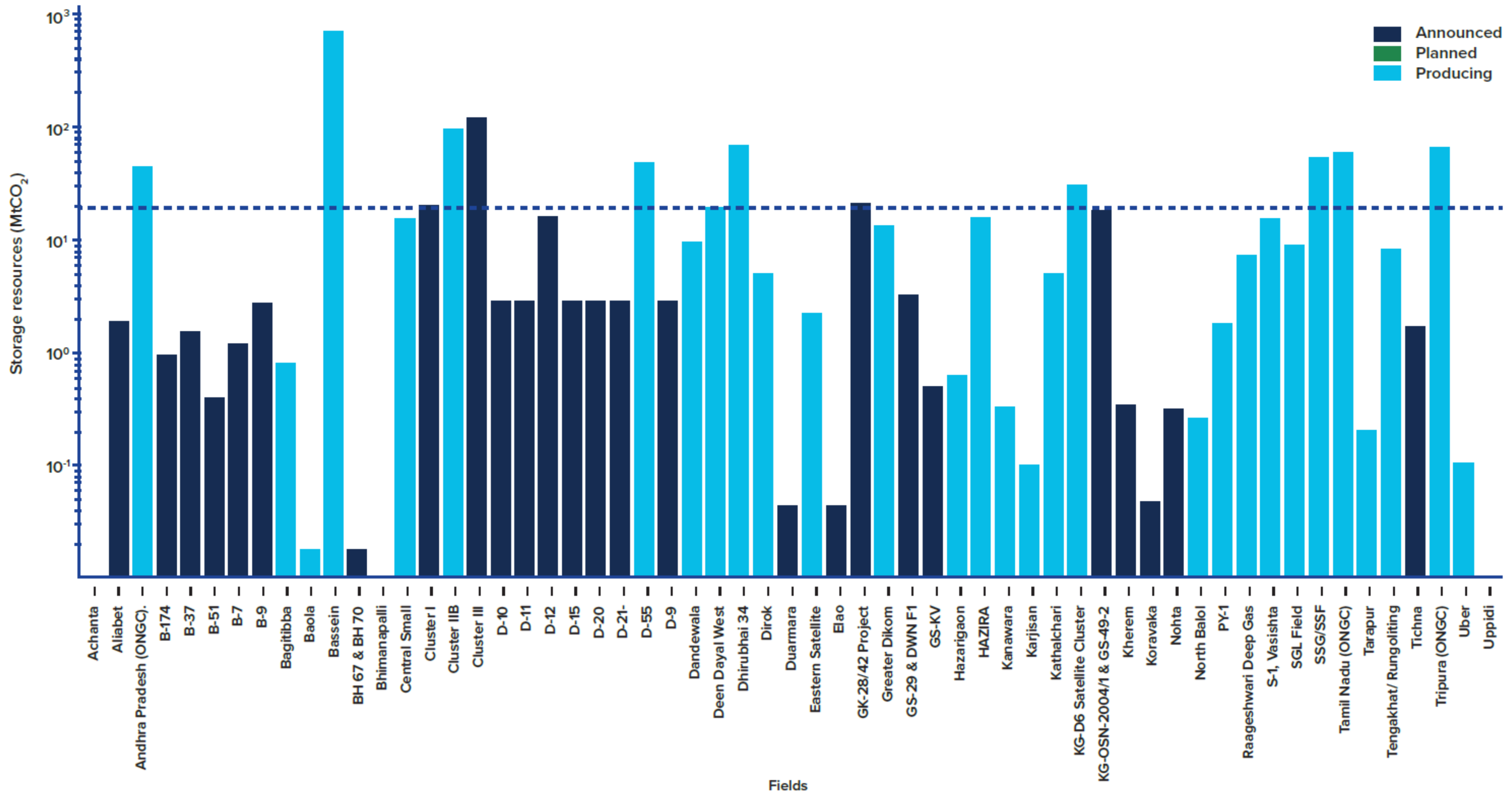


01. Krishna-Godavari (KG)
02.Mumbai Offshore
03. Assam-Shelf
04. Rajasthan
05. Cauvery
06. Assam-Arakan Fold Belt
07. Cambay
08. Saurashtra
09. Kutch
10. Vindhyan
11. Mahanadi
12. Andaman
13. Kerala-Konkan (KK)
14. Bengal-Purnea
15. Ganga-Punjab
16. Pranhita-Godavari (PG)
17. Satpura- South Rewa-Damodar
18. Himalayan Foreland
19. Chhattisgarh
20. Narmada
21. Spiti-Zanskar
22. Deccan Syneclise
23. Cuddapah
24. Karewa
25. Bhima-Kaladgi
26. Bastar

CO2 STORAGE RESOURCES OF CONVENTIONAL OIL FIELDS



CO2 STORAGE RESOURCES OF CONVENTIONAL GAS FIELDS



CO2 STORAGE RESOURCES OF CONVENTIONAL OIL AND GAS FIELDS

Oil fields

FIELD NAME	BASIN	ONSHORE/ OFFSHORE	P50 ($MTCO_2$)	EXTRACTION EFFICIENCY OIL (%)	EXTRACTION EFFICIENCY GAS (%)
Mumbai High	Mumbai Offshore	Shallow Water	299.97	73	56
Gujarat	Cambay	Onshore	52.13	60.5	81.5
Greater Jorajan	Assam-Arakan	Onshore	21.51	98	95
Greater Nahorkatiya	Assam-Arakan	Onshore	26.27	99	98
Panna-Mukta	Mumbai Offshore	Shallow Water	33.54	99	99

Gas fields

FIELD NAME	BASIN	ONSHORE/ OFFSHORE	P50 ($MTCO_2$)	EXTRACTION EFFICIENCY OIL (%)	EXTRACTION EFFICIENCY GAS (%)
Andhra Pradesh	Krishna-Godavari	Onshore	44.5	67.50	82.12
Bassein	Mumbai Offshore	Shallow Water	696.0	55.52	76.09
Cluster IIB	Krishna-Godavari	Deepwater	98.4	NA	3.98
Cluster III	Krishna-Godavari	Ultra-Deepwater	118.4	NA	0.00
D-55	Krishna-Godavari	Deepwater	50.5	NA	
Dhirubhai 34	Krishna-Godavari	Ultra-Deepwater	66.6	NA	20.51
SSG/SSF	Rajasthan	Onshore	55.2	NA	8.25
Tamil Nadu	Cauvery	Onshore	58.0	81.47	58.35
Tripura	Assam-Arakan	Onshore	66.6	5.53	44.08
Cluster I	Krishna-Godavari Basin	Deepwater	20.2	NA	0.00
GK-28/42 Project	Kutch Basin	Shallow Water	21.2	0.00	0.00
KG-D6 Satellite Cluster	Krishna-Godavari Basin	Deepwater	31.5	NA	16.3

CO2 STORAGE RESOURCES OF CONVENTIONAL OIL AND GAS FIELDS

Cumulative storage resources in oil fields by basin

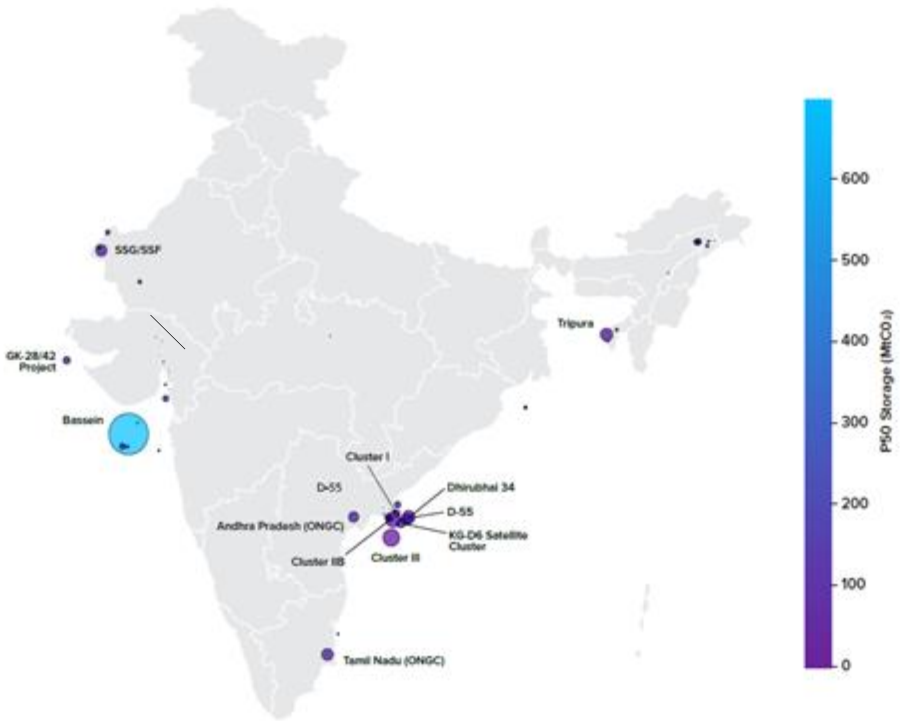
BASIN	P50 ($MTCO_2$)
Assam-Arakan Basin	111.97
Cambay Basin	61.89
Cauvery Basin	0.48
Krishna-Godavari Basin	23.63
Kutch Basin	0.12
Mumbai Offshore Basin	338.47
Rajasthan Basin	18.38
Net storage resources	554.93

Cumulative storage resources in gas fields by basin

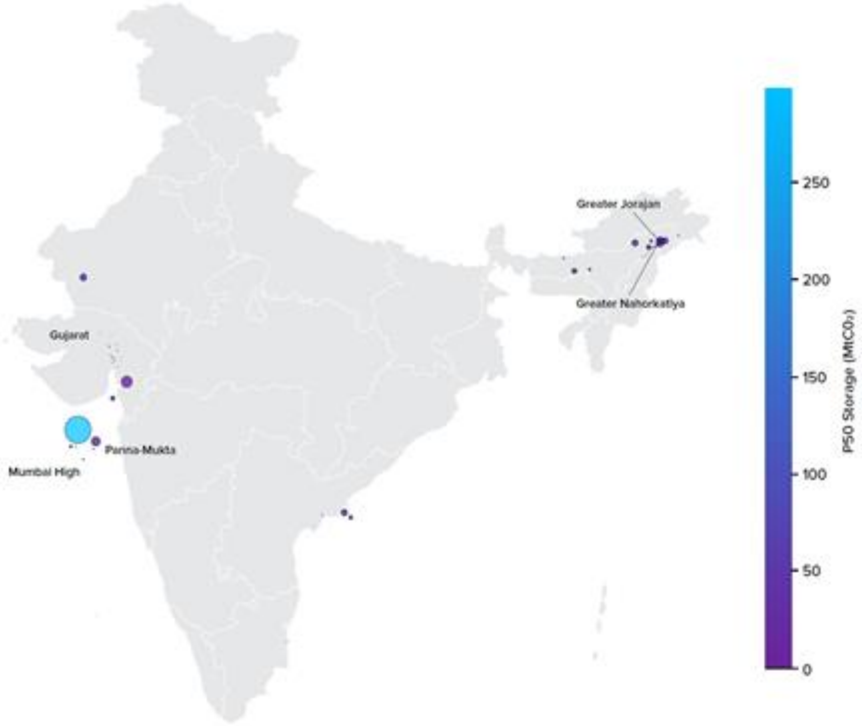
BASIN	P50 ($MTCO_2$)
Assam-Arakan Basin	119.09
Cambay Basin	18.41
Cauvery Basin	59.80
Krishna-Godavari Basin	486.20
Kutch Basin	21.15
Mahanadi Basin	17.03
Mumbai Offshore Basin	722.43
Rajasthan Basin	81.70
Vindhyan Basin	0.31
Net storage resources	1,526.13

CO2 STORAGE RESOURCES OF CONVENTIONAL OIL AND GAS FIELDS

Gas fields



Oil fields



Wells

CO2 STORAGE RESOURCES OF SALINE FORMATIONS: EXISTING STUDIES

There have been no published comprehensive formation scale studies (in English) on the geological CO_2 storage potential of saline formations in India for which supporting data is available.

Existing studies primarily calculate storage resources at the basin scale.

Estimated net CO_2 storage resources in saline formations in India

REFERENCE	STORAGE RESOURCES (GIGATONNE CO_2)
IEA [12]	63
Holloway et al. [13]	63
Singh et al. [16]	360
Bakshi et al. [15]	325
Vishal et al. [17]	291

CO2 STORAGE RESOURCES OF SALINE FORMATIONS: THIS STUDY

Used a 1D volumetric approach for resource estimation.

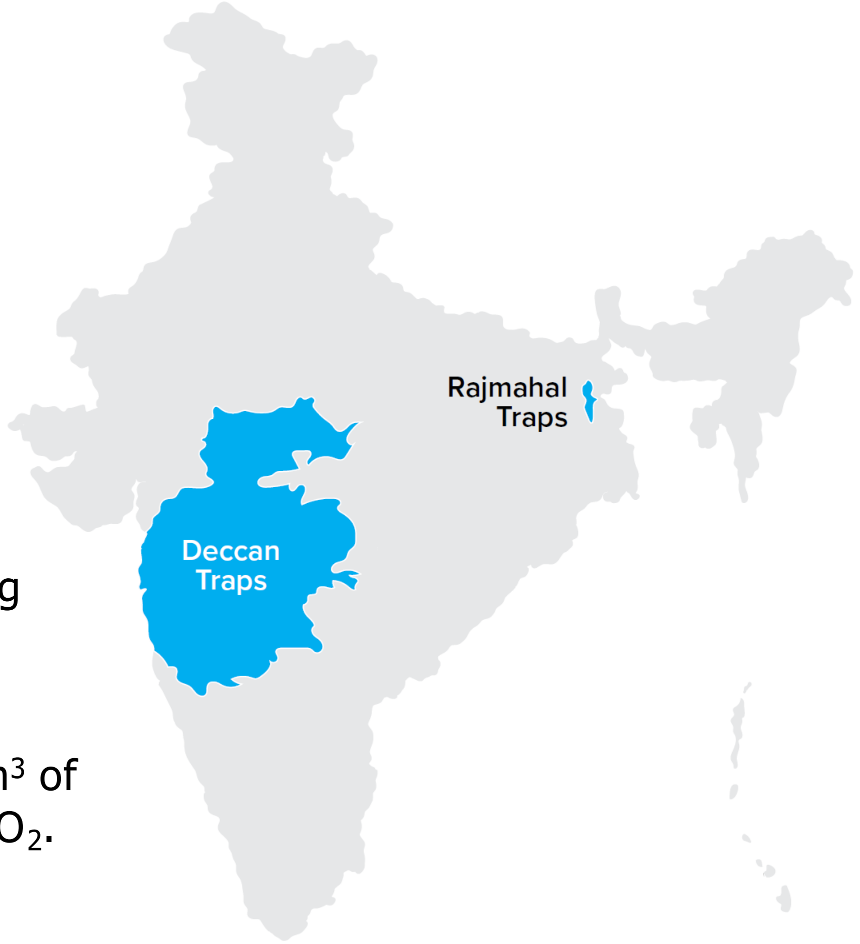
$$M_{CO_2} = A.H.\emptyset.E.\rho$$

Results presented should only be considered as a high-level theoretical values for understanding of the net storage resources in the saline formations of each basin.

Used approach assumes the existence of open boundaries, which may not apply to all saline formations.

BASIN	CATEGORY	NET AREA (KM²)	AREA - ONSHORE (KM²)	AREA - OFFSHORE - SHALLOW (WATER DEPTH <400 M) (KM²)	AREA OFFSHORE-DEEP (KM²)	NET RESOURCES ($GTCO_2$) P50	ONSHORE RESOURCES ($GTCO_2$) P50	OFFSHORE-SHALLOW (WATER DEPTH <400 M) RESOURCES ($GTCO_2$) P50	OFFSHORE-DEEP RESOURCES ($GTCO_2$) P50	STORAGE RESOURCES (%)
Krishna-Godavari Basin	1	230,000	31,456	25649	172895	42.24	5.78	4.71	31.75	29.70
Mumbai Offshore Basin	1	212,000	0	118389	93611	38.94	0.00	21.74	17.19	
Rajasthan Basin	1	126,000	126,000	0	0	23.14	23.14	0.00	0.00	
Cauvery Basin	1	240,000	37,825	43723	158452	44.08	6.95	8.03	29.10	
Assam-Arakan Basin	1	136,825	136,825	0	0	25.13	25.13	0.00	0.00	
Cambay Basin	1	53,500	48,882	4618	0	9.83	8.98	0.85	0.00	
Saurashtra Basin	2	194,114	75,076	42617	76421	35.65	13.79	7.83	14.04	26.80
Kutch Basin	2	58,554	30,754	20500	7300	10.75	5.65	3.77	1.34	
Vindhyan Basin	2	202,888	202,888	0	0	37.26	37.26	0.00	0.00	
Mahanadi Basin	2	99,500	15,500	14211	69789	18.27	2.85	2.61	12.82	
Andaman-Nicobar Basin	2	225,918	0	18074	207844	41.49	0.00	3.32	38.17	
Bengal Basin	2	121,914	42,414	33465	46035	22.39	7.79	6.15	8.45	
Total storage resources for all the basins (GTCO2)						618	300	76	243	

CO2 STORAGE RESOURCES OF BASALTS



Deccan Traps

- One of the world's largest continental flood-basalt provinces.
- Area ≈ 500,000 km^2
- Thickness: from a few meters in the east to over 2.5 km in the west.
- Estimated volume ≈ 512,000 km^3.

Rajmahal Trap

- Area ≈ 18,000 km^2.
- Thickness: 450 to 600 m.
- The central part contains over 28 lava flows, each with a thickness ranging from 20 to 70 m

Published assessments rely on broad storage factors, such as 41 and 70 kg CO_2/m^3 of rock. Their results indicate a net storage resource ranging between 97 to 316 $GtCO_2$.

These extensive flood basalts may hold significant potential for in-situ carbon mineralization. However, the absence of essential subsurface data prevents the estimation of their mineral carbonation potential in this study.

CONCLUSIONS

- Sedimentary basins in India have the potential to offer multi-gigaton storage resources for CO_2.
- Basins with a high level of hydrocarbon exploration and production maturity (Category 1) had data available, enabling an analysis of early opportunities.
- Regarding CO_2 storage in oil and gas fields, the study finds that most studied fields are small, with only five oil and twelve gas fields having storage resources over 20 $MtCO_2$, suitable for medium to large-scale CCS projects. Among these, only three oil fields are nearly depleted and ready for storage, while the rest will become available in the medium to long term.
- Considering the significant size of the basalt formations in India, they may have significant potential for in-situ mineralisation if certain geological and geochemical conditions exist.

RECOMMENDATIONS

- The study underscores a significant lack of publicly available data for a more comprehensive assessment of CO_2 storage resources in saline formations across all basins. Consequently, the reported values in this study, as well as those at basin scale in the literature, are subject to uncertainty, emphasizing the urgent need to take action on gathering and publishing the required subsurface data.

- This study identifies fields with CO_2 storage resources exceeding 20 Mt, which can potentially facilitate commercial-scale CCS deployment. However, the suitability of these fields for CCS project development requires further detailed studies, such as assessing injectivity, sealing capacity of the top seal, and the impact of faults, among other factors.

- In-situ carbon mineralisation in basalts formations in India may offer sizeable storage resources for CO_2. Therefore, it is critical to conduct required measurements and studies to assess their suitability and calculate their storage resources.

Jerrad Thomas

GCCSI

SOURCE-SINK MATCHING IN INDIA

Jerrad Thomas

Global CCS Institute

Source-Sink Matching Efforts in India

Source-Sink Matching

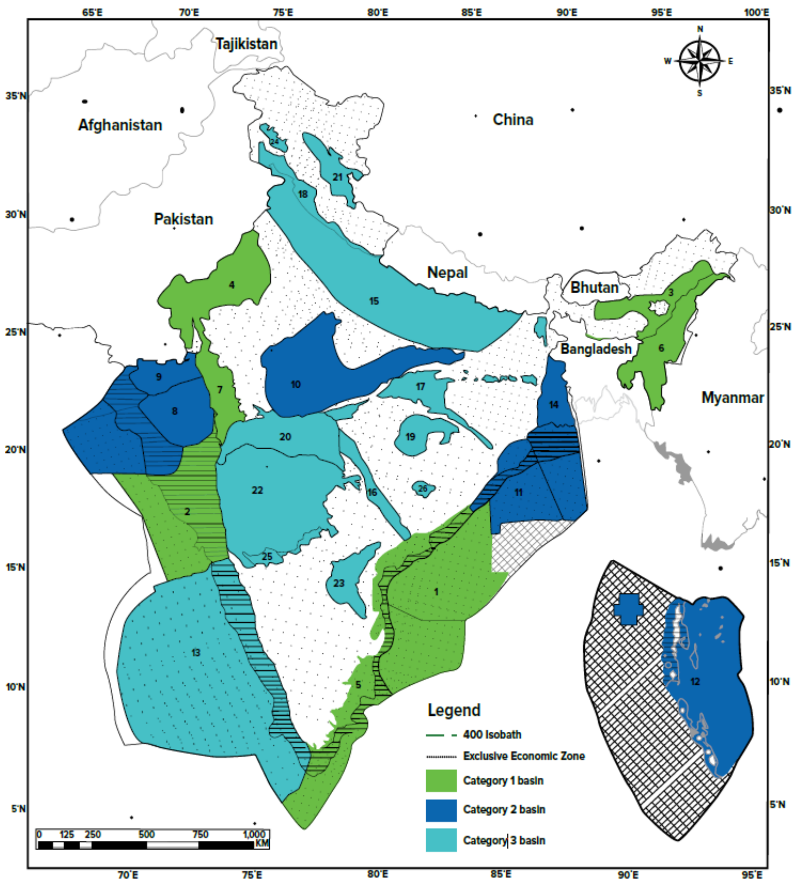
- The pairing of emitters with suitable storage sites
- Crucial for developing CCS hubs – reduces transportation costs

Key Findings

- [29] Global CCS Institute (2021) – Identified five potential CO2 source-sink networks.
- [25] National University of Singapore (2022) – Identified four potential CCS hubs.
- [30] Indian Institute of Technology (2013) – Suggested Krishna-Godavari Basin as an ideal long-term storage site for power generation emitters.
- [43] Synergia Energy Hub (2023) – Commercial project announced in 2023 to sequester emissions in the Cambay basin with a capacity up to 43 MtCO2/year.

SOURCE	EMITTER REGION	STORAGE BASIN	ESTIMATED MID CAPACITY ($MTCO_2$)(2)
[29]	Coastal Gujarat and Mumbai	Mumbai Offshore	Not Listed
	Coastal Andhra Pradesh	Krishna-Godavari Offshore	Not Listed
	Kolkata	Onshore Bengal	Not Listed
	Chennai and surrounding	Cauvery-Palar	Not Listed
[25]	Mumbai	Mumbai Offshore	34,800
	Nagpur	Narmada Basin	5,100
	Chandrapur	Pranhita-Godavari	4,500
	Hazira	Mumbai Offshore and Narmada	39,900
[30]	Various Power Stations	Krishna-Godavari	150
[43]	Proximal to Basin	Cambay	500 (2)

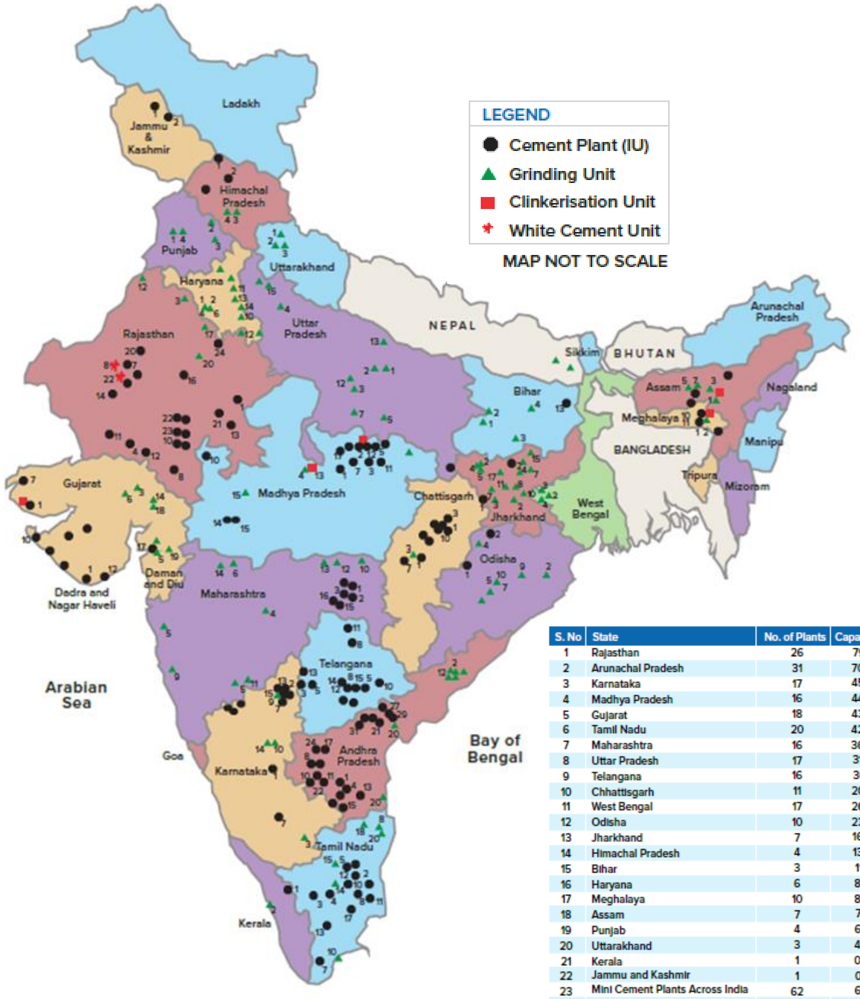
Table 16: Inventory of Source-Sink Matching or Potential Hubs in India.



01. Krishna-Godavari (KG)
02. Mumbai Offshore
03. Assam-Shelf
04. Rajasthan
05. Cauvery
06. Assam-Arakan Fold Belt
07. Cambay
08. Saurashtra
09. Kutch
10. Vindhyan
11. Mahanadi
12. Andaman
13. Kerala-Konkan (KK)
14. Bengal-Purnea
15. Ganga-Punjab
16. Pranhita-Godavari (PG)
17. Satpura- South Rewa-Damodar
18. Himalayan Foreland
19. Chhattishgarh
20. Narmada
21. Spiti-Zanskar
22. Deccan Syneclise
23. Cuddapah
24. Karewa
25. Bhima-Kaladgi
26. Bastar

Figure 2: Sedimentary basins of India.

Cement Plant Cluster Analysis – Overview



S. No	State	No. of Plants	Capacity (mt)
1	Rajasthan	26	79.51
2	Arunachal Pradesh	31	70.54
3	Karnataka	17	45.32
4	Madhya Pradesh	16	44.55
5	Gujarat	18	43.52
6	Tamil Nadu	20	42.92
7	Maharashtra	16	36.40
8	Uttar Pradesh	17	31.85
9	Telangana	16	30.71
10	Chhattisgarh	11	20.27
11	West Bengal	17	26.27
12	Odisha	10	23.45
13	Jharkhand	7	16.35
14	Himachal Pradesh	4	13.30
15	Bihar	3	11.10
16	Haryana	6	8.96
17	Meghalaya	10	8.50
18	Assam	7	7.22
19	Punjab	4	6.57
20	Uttarakhand	3	4.00
21	Kerala	1	0.50
22	Jammu and Kashmir	1	0.76
23	Mini Cement Plants Across India	62	6.42
	Total	328	994.14

Figure 21: Cement map of India. As of November 2022.

Cement Plant Screening and Emissions Estimating

- 328 identified total cement facilities screened to 259
- 101 facilities included in the cluster analysis – small sources and sites without emissions or production data were excluded
- Where not available, CO2 emissions estimated using overall cement production data provided by GCCA and a carbon emissions intensity derived from the GNR database of 0.821 tCO2/tonne clinker (process + thermal emissions)

Clustering Analysis

- Aims to understand spatial distribution and density by grouping similar data points based on predefined criteria
- Identifies patterns and structures within large datasets

Clustering Methods

- *K-Means Clustering* – Divides data into k clusters based on centroids and most effective for well-separated clusters
- *Hierarchical Clustering* – Builds a hierarchy of clusters using a tree-like structure but computationally intensive and less effective for large datasets
- *DBSCAN (Density-Based Spatial Clustering of Applications with Noise)* – Groups data points based on density and distance with strong ability to handle noise and outliers

Cement Plant Cluster Analysis – Clustering Results

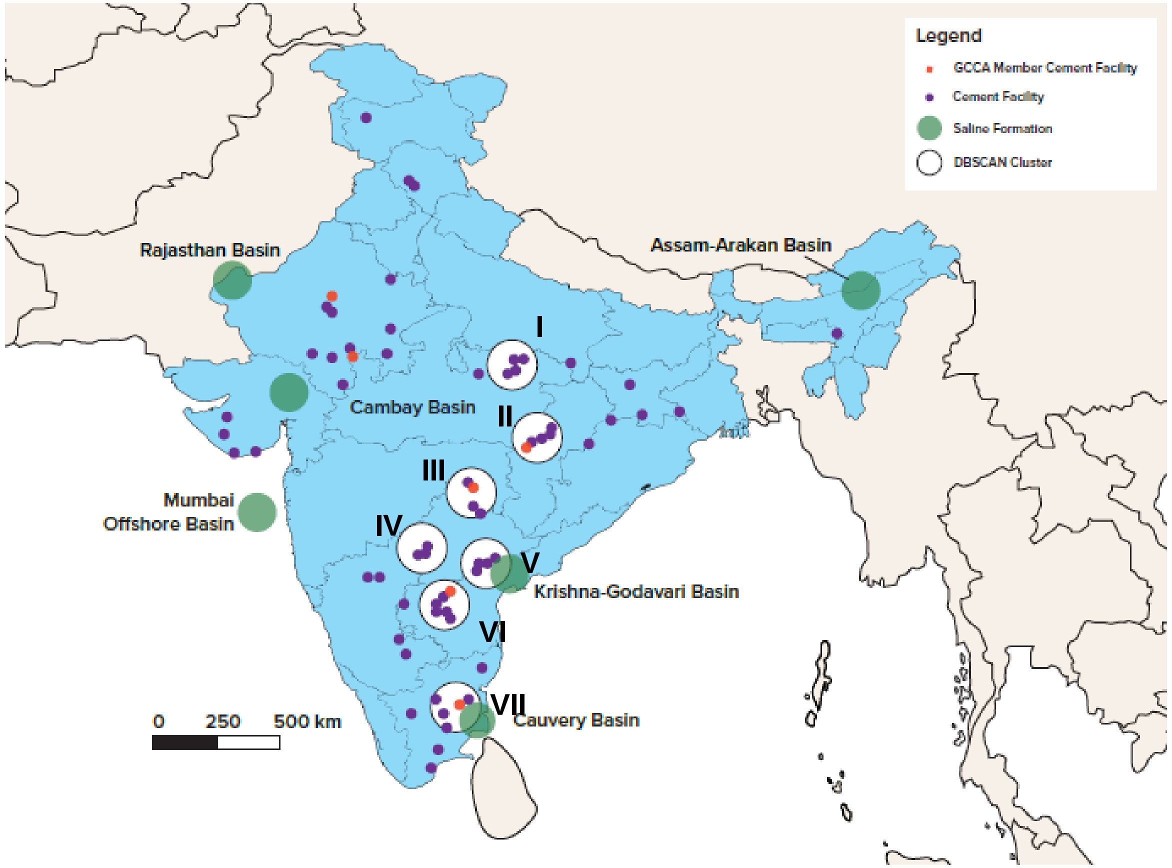


Figure 23: Cluster analysis results with Category 1 basins shown.

DBSCAN Results

- Parameters set to a minimum of 5 facilities per hub and a maximum distance between points of 1 degree (approximately 100 km maximum between facilities) using Quantum GIS version 3.34.2
- Seven identified clusters as shown in Table 17 and Figure 22

CLUSTER ID	NUMBER OF FACILITIES	TOTAL EMISSIONS (MTPA CO_2)
I	6	10.6
II	6	9.1
III	6	11.2
IV	7	10.7
V	18	19.9
VI	12	17.6
VII	8	11.9

Table 17: Results of clustering analysis by DBSCAN.

- Clusters V and VI show largest number of facilities with most emissions
- Cluster V is near the the Krishna-Godavari basin
- Cluster VII is near the Cauvery basin
- Clusters V and VII nearest a Category 1 basin
- Cluster V selected for Technoeconomic Analysis due to a combination of many facilities and proximity to a Category 1 basin

Technoeconomic Analysis – Capture Basis

Cost of Capture Basis

- Lehigh Edmonton Cement Plant chosen as cost of capture basis due to recently completed feasibility study
- Richardson construction cost factors were used to adapt construction costs from Canada (0.98) to India (1.01), resulting in a factor of 1.03
- Variable OPEX: $27.49 USD/tonne (2021)
- CAPEX scaled with six-tenths scaling based on

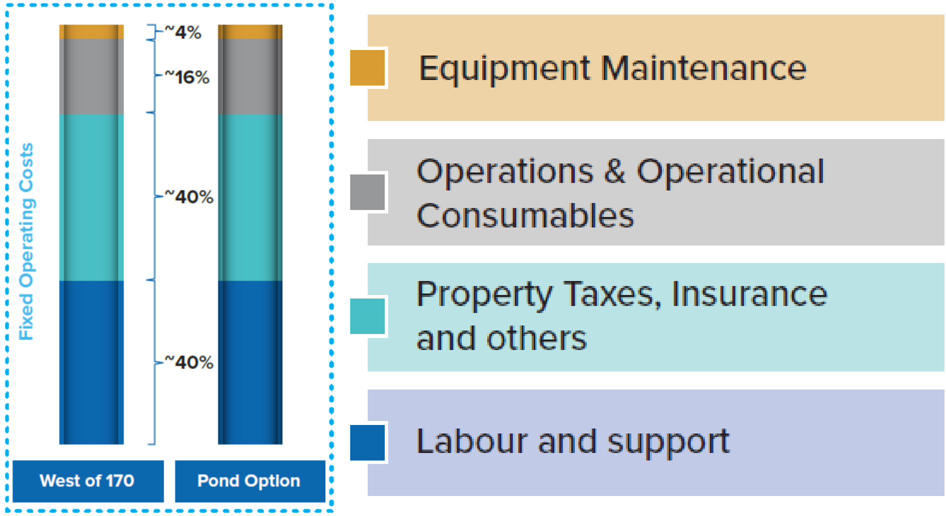


Figure 24: Breakdown of fixed operating costs from the Edmonton Study.

Facility	Lehigh Edmonton Cement Plant
Location	Edmonton, AB, Canada
Capacity	0.78 Mtpa CO_2
Capital Cost	511.36 million USD (2021)[3]
Fixed Operating Cost	7.75 million USD/y (2021)[3]
Variable Operating Cost	21.44 million USD/y (2021)[3]

Table 19: Basis information for the carbon capture capital and operating cost estimates.

Fixed Operating Costs

- *Equipment Maintenance* – The Edmonton study shows a lower maintenance cost than expected. Literature suggests 2% of equipment procurement.
- *Operations & Operational Consumables* – This study assumes that this value is fixed on a per tonne basis for every plant.
- *Property Taxes, Insurance, and Others* – This item relates to the size and value of the overall plant, and it is assumed to be consistent with Edmonton.
- *Labour and Support* – Regardless of scale, these facilities require a similar number of operators and support staff. Therefore, this portion is fixed per the Edmonton study.

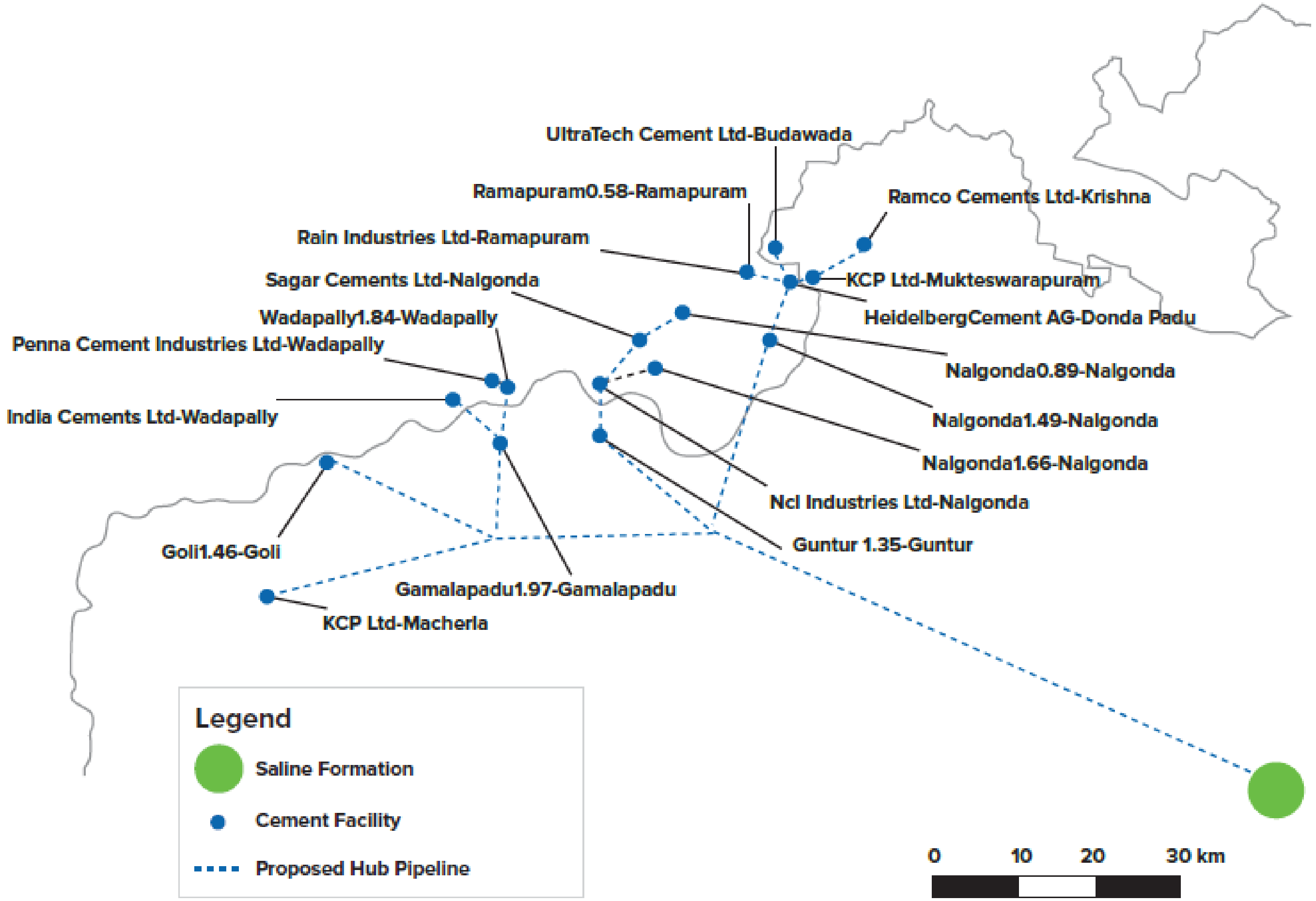
Technoeconomic Analysis – Cost of Capture

PLANT NAME	EMISSIONS ($MTCO_2/Y$)	TOTAL CAPITAL COST (MUSD)	ANNUALISED CAPITAL COST (MUSD/Y)	TOTAL OPERATING COSTS (MUSD/Y)	COST OF CAPTURE (USD/TCO_2)
Gamalapadu1.97-Gamalapadu	1.2	681	69	49	98.8
Goli1.46-Goli	0.9	569	58	37	106.5
Guntur1.35-Guntur	0.8	544	55	34	108.7
HeidelbergCement AG-Donda Padu	1.5	767	78	59	94.1
India Cements Ltd-Wadapally	1.5	786	80	61	93.2
KCP Ltd-Macherla	0.4	365	37	18	130.3
KCP Ltd-Mukteswarapuram	2.1	965	98	86	86.1
Nalgonda0.89-Nalgonda	0.5	422	43	23	121.8
Nalgonda1.49-Nalgonda	0.9	576	59	37	106.0
Nalgonda1.66-Nalgonda	1.0	614	63	41	103.1
Ncl Industries Ltd-Nalgonda	1.3	708	72	52	97.2
Penna Cement Industries Ltd-Wadapally	0.7	506	52	30	112.2
Rain Industries Ltd-Ramapuram	0.8	531	54	33	109.8
Ramapuram0.58-Ramapuram	0.4	328	33	15	137.3
Ramco Cements Ltd-Krishna	2.2	986	100	89	85.3
Sagar Cements Ltd-Nalgonda	1.1	649	66	45	100.8
UltraTech Cement Ltd-Budawada	1.4	760	77	58	94.5
Wadapally1.84-Wadapally	1.1	654	67	46	100.5

Cost of Capture

- Capture cost includes the inside battery limits as well as balance of plant capital costs.
- A cost of capital of 10.5% was used. This was based on the cost of capital for a gas turbine installed in India in 2021 reported by the IEA.
- Compression costs are included, but these do not include cost for transport, which are estimated separately.

Technoeconomic Analysis – Transportation



<u>Pipeline CO2 Transportation</u>

- As the initial step, the pipeline was segmented according to facility locations in the identified hub.
- Capital and operating costs for pipelines were estimated for each segment of the proposed hub. All pipelines are designed to suit supercritical operating pressures.
- Pipeline sizing was based on the overall CO2 flow expected for that given pipeline up to the maximum standard nominal pipe size of 600mm.
- Once length, pipe diameter, and schedule were determined, cost estimates were made for each pipeline segment in this study.

Technoeconomic Analysis – Hub Versus Single Case

SEGMENT LENGTH (KM)	CO_2 FLOW (Mtpa CO_2)	# PARALLEL PIPELINES	PIPELINE DIAMETER (mm)	TOTAL CAPITAL COST MUSD	ANNUALISED CAPITAL COSTS MUSD/Y	ANNUAL O&M (MUSD/Y)	TOTAL ANNUALISED COSTS (MUSD/Y)	UNIT COST OF TRANSPORT (USD/TCO_2)
287.4	19.9			603.9	63.4	6.0	69.5	3.5

Table 21: Krishna-Godavari hub pipeline segment and overall hub costs. (Modified)

Hub Transport Costs

Single Case Transport Costs

SEGMENT LENGTH (KM)	CO_2 FLOW (Mtpa CO_2)	# PARALLEL PIPELINES	PIPELINE DIAMETER (mm)	TOTAL CAPITAL COST MUSD	ANNUALISED CAPITAL COSTS MUSD/Y	ANNUAL O&M (MUSD/Y)	TOTAL ANNUALISED COSTS (MUSD/Y)	UNIT COST OF TRANSPORT (USD/TCO_2)
130.7	0.43	1	200	154.1	16.2	1.5	17.7	34.7

Table 22: Individual cement plant with carbon capture and storage case pipeline cost.

Mojtaba Seyyedi
mojtaba.seyyedi@globalccsinstitute.com

Jerrad Thomas
Jerrad.thomas@globalccsinstitute.com

gcca CARBON CAPTURE, UTILIZATION & STORAGE ACCELERATING CCUS TOGETHER AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL GLOBAL CCS FOUNDATION GLOBAL CCS INSTITUTE

Vikram Vishal

IIT Bombay

Speaker:

Vikram Vishal

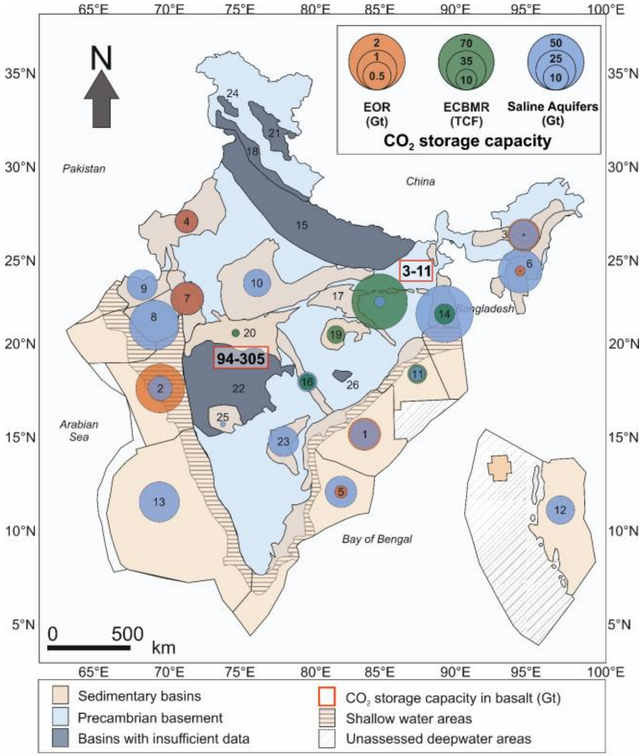
Convenor
DST-National Centre of Excellence in Carbon Capture and Utilization

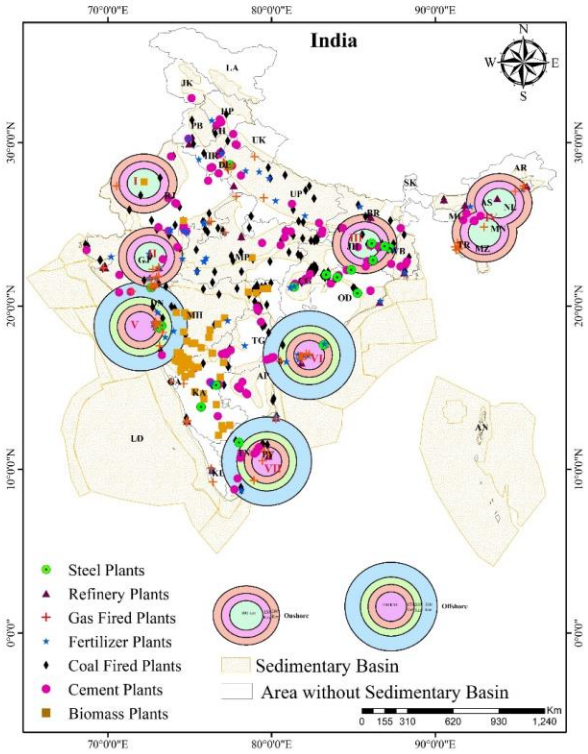
Professor, Earth Sciences, and IDP-Climate Studies
Indian Institute of Technology Bombay, Mumbai

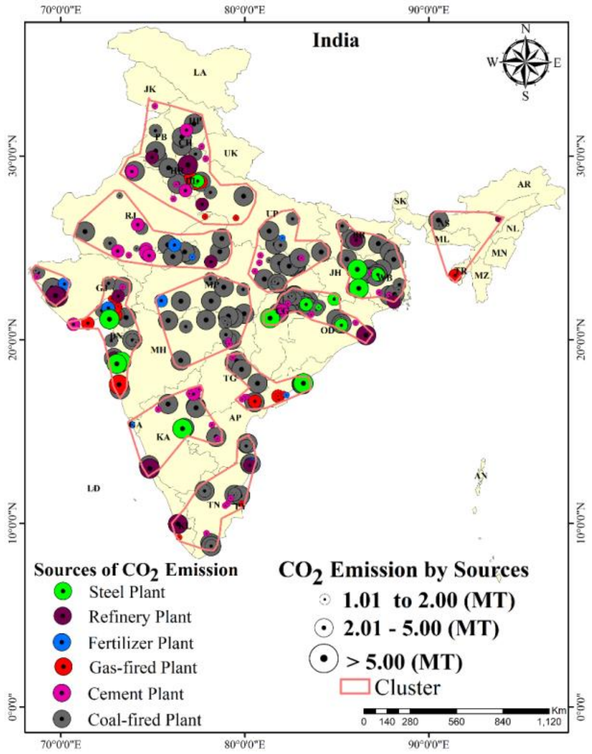
Founder and Director, UrjanovaC Pvt Ltd

Cross-sectoral source-sink matching and CCS hub-clusters in India

1. Geological storage potential, mapped with the large point sources (LPSs) of CO_2 emissions in India
2. 244 LPSs and 7 sedimentary basins (3 offshore and 4 onshore) considered for the study
3. 106 LPSs with more than 1 Mt average annual emission mapped for clusters



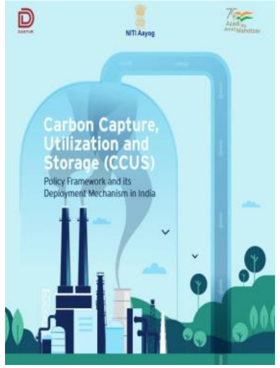


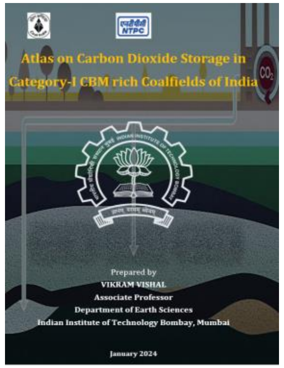


Vishal et al., 2021, International Journal of Greenhouse Gas Control, Vol. 111, p.103458.
Vishal et al. 2022, Geological Society of London Special Publications., Vol. 528 (1), Art. SP528-2022-76

Recent CCUS Advancements in India

- India to account for ~20% of global industrial CCS by 2060. (Ref: IEA Report)
- NITI Aayog spearheaded the development of the 'CCUS policy frameworks and its deployment mechanism in India'.
- Department of S&T, Govt of India established three National Centres of Excellence in CCUS
- Bureau of Indian Standards has adopted the ISO standards on CCS.
- Bureau of Energy Efficiency building on Carbon Market Framework for CCUS.
- G-20 Technical and Financial reports highlight that storage assessments, acceptance in global carbon markets, and G20 level supportive policies would encourage investments in CCS.
- Ministry of Power & Ministry of Environment, Forests & Climate Change building on the Carbon Credit Trading Scheme for decarbonization.
- Four inter-ministerial taskforce on CCUS – for techno-policy guidelines for implementation of CCUS.
- World Bank – IIT Bombay study on 'Global Climate Change Awareness and CCUS Perception in India'
- Scoping to pre-feasibility level assessment of geological CO_2 storage in depleting oilfields, coal seams, aquifers and basalts





Recommendations

It is recommended that:

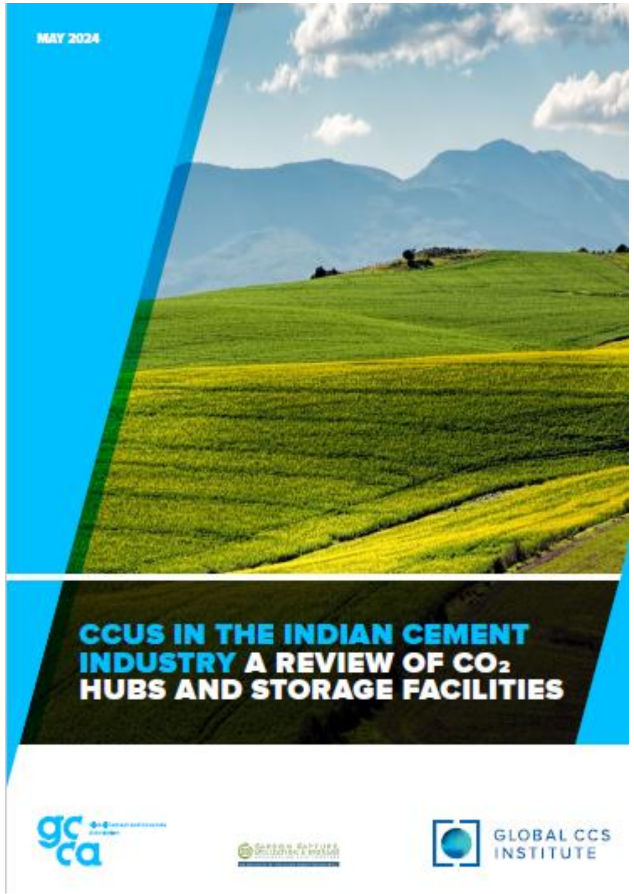
- Given the significant lack of publicly available data for a reliable assessment of CO_2 storage resources in saline formation across all basins, collaborative action is taken with all actors in India to gather and publish the required subsurface data.

- In light of the study findings, GCCA members to identify 2 to 3 first movers of flagship CCS projects within the potential hubs identified.

- Given that India presents a unique (next to Siberia) continental flood basalt basin, which may hold significant potential for in-situ carbon mineralisation, it is recommended to conduct specific measurements to calculate storage factors.

- The report also highlights the essential need to provide reliable access to sufficient and competitively priced decarbonised energy, as a carbon capture unit powered solely by coal would more than double a cement plant’s energy needs.

CCUS in the Indian Cement Industry: A Review of CO_2 Hubs and Storage Facilities



- This is the first report in a series for India - developed collaboratively between the Global CCS Institute, Clean Energy Ministerial CCUS Initiative, and Global Cement and Concrete Association, and with support from the Global CCS Foundation, assesses:
    - Potential CCUS hub ecosystems in India and identifies potential flagship projects
    - CO_2 emission sources with storage opportunities in proximity
    - Transport and storage costs through a techno-economic analysis, and more

Global Cement and Concrete Association

CARBON CAPTURE, UTILIZATION & STORAGE
ACCELERATING CCUS TOGETHER
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

GLOBAL CCS FOUNDATION

GLOBAL CCS INSTITUTE

Next steps

- Outcome 2: Policy, regulatory and financial frameworks for CCUS in India
  - The definition of enabling policy and financing frameworks to help create a pipeline of bankable CCUS projects in India.
  - Analysis and drafting under way
- 15th Clean Energy Ministerial, Brazil 1-3 October 2024
  - Presentation of work at high-level side-event
  - Announcing next focus country / region (TBC)
- Outcome 3 : The identification of “First-mover” or “Flagship” CCUS pilot projects and pre-feasibility studies for those.
- Capacity building
- Replicate this approach for a number of regions and countries across the world (with a strong focus on the global south) to help accelerate deployment of CCUS.

CEM15 MI-9 FOZ DO IGUAÇU BRASIL · 2024

Global Cement and Concrete Association

CARBON CAPTURE, UTILIZATION & STORAGE ACCELERATING CCUS TOGETHER AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

GLOBAL CCS FOUNDATION

GLOBAL CCS INSTITUTE