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King Abdullah Petroleum Studies and Research Center

Commentary

Enabling the Progress of the Circular Carbon Economy: India's Approach to CCUS

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Summary

The circular carbon economy (CCE)[1] concept is an extension of the idea of a circular economy, focusing on energy and carbon flows while implicitly retaining the circular economy's material, energy, water, and economic flows. The goal of the CCE framework is to achieve a carbon balance or net-zero emissions in the second half of the twenty-first century; as such, the circularity of material flows is secondary to the circularity of carbon flows when they are in conflict (King Abdullah Petroleum Studies and Research Center 2020). This commentary focuses on the carbon capture, utilization, and storage (CCUS) components of the CCE framework, highlighting the relevance of the framework in the context of India. Furthermore, this paper aims to explore the following elements of the Indian CCUS landscape:

- Policy initiatives undertaken by the government of India
- Stakeholders involved in the Indian CCUS program
- Status of ongoing CCE-enabled projects
- Future initiatives by India to adopt CCUS technology

Introduction

Reaching net-zero emissions (NZE) by 2070 was one of the five promises made by the Indian prime minister at the 26th United Nations Climate Change Conference (COP26) held in Glasgow, United Kingdom, in 2021 (Bhatt, Sergeeva and Efird 2021). The prime minister also emphasized the importance of the circular carbon economy (CCE) approach in the Indian economy to achieve the climate goals of the Group of 20 (G20) Summit Side Event, "Safeguarding the Planet—The Circular Carbon Economy Approach," during the 2020 Saudi presidency of the G20 (Ministry of External Affairs 2020).

For a developing country such as India, which has a population of 1.4 billion, achieving its NZE ambitions calls for a complete and just transformation of all sectors. India is the 3rd largest GHG emitter in the world, although its per capita emissions are below the global average (BBC 2021). It is also highly vulnerable to climate change, with regular extreme weather events impacting the country (Mohanty and Wadhawan 2022).

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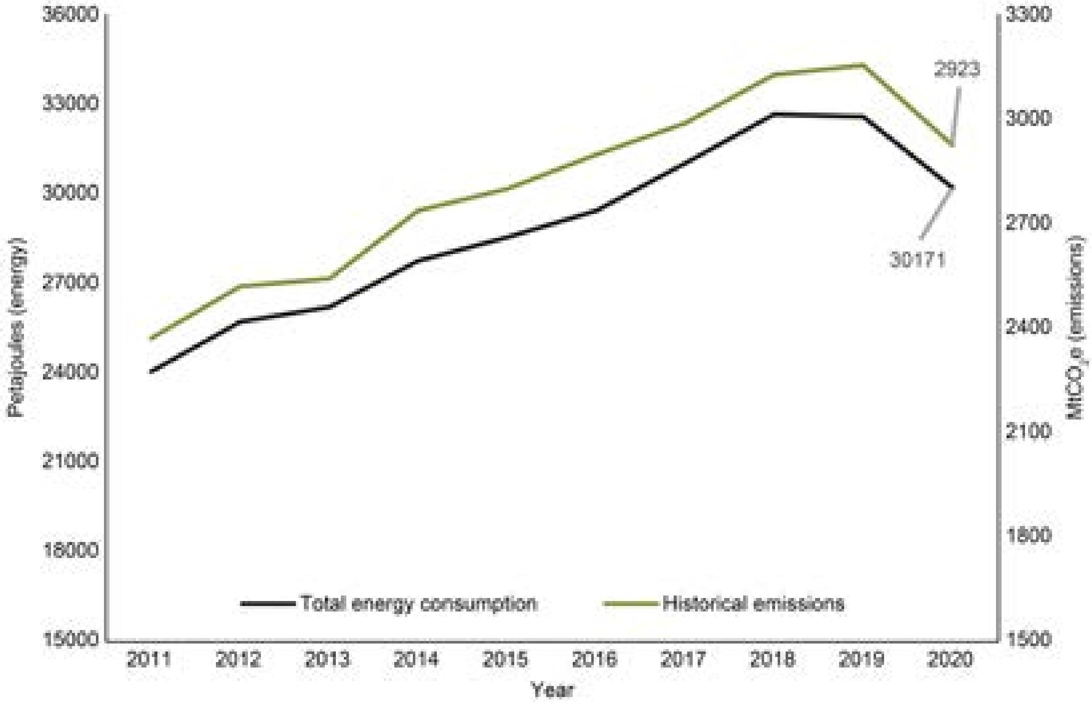
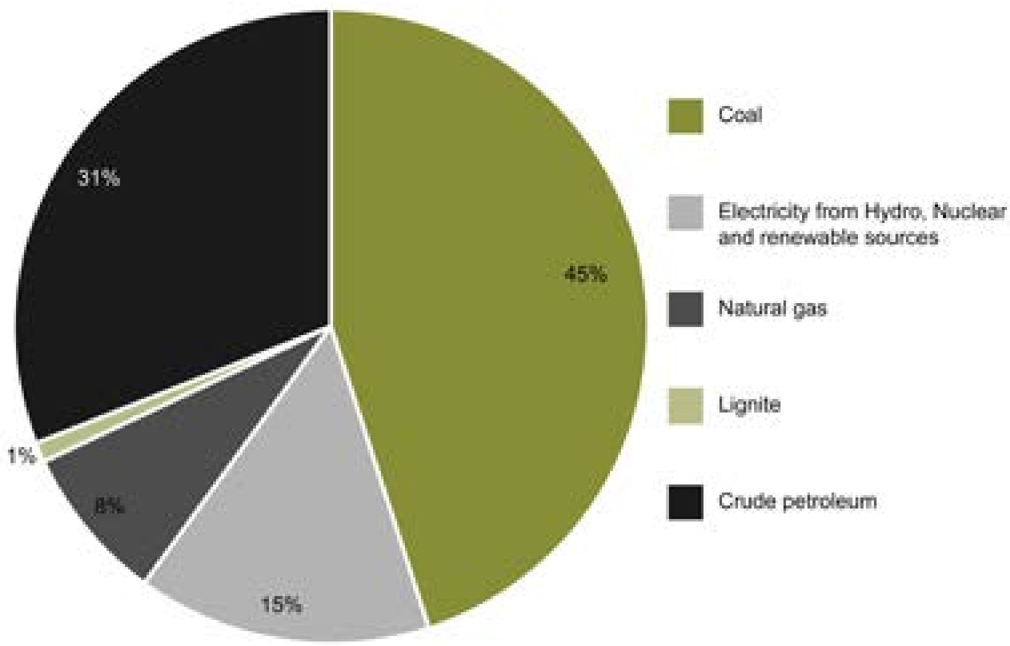
[1] "The circular carbon economy (CCE) concept provides a holistic, flexible, and pragmatic framework for countries to plan their respective contributions toward the commonly agreed climate goals" (KAPSARC 2020a). For a more detailed understanding of the CCE concept, please visit www.cceguide.com.

Figure 1. India's historical emissions and energy consumption from 2011 to 2020, including fuel-wise energy consumption in 2020



Source: Climate Action Tracker and Ministry of Statistics and Programme Implementation, Government of India.

Figure 2. Fuel-wise consumption of energy in 2020



Source: Central Electricity Authority of India.

In the past decade, India's total energy consumption and emissions have grown steadily, with only a slight decrease in 20202 due to confinement measures taken by India during the COVID-19 pandemic (see Figure 1). Before the COVID-19 pandemic, the India Energy Outlook of the International Energy Agency (IEA) projected that India's energy demand would increase by approximately 50% between 2019 and 2030; after the pandemic, the IEA projected a growth of approximately 35% in its Stated Policies Scenario (STEPS)[2] (business as usual) (IEA 2021). The BP Energy Outlook projected that under all three scenarios (accelerated, NZE, and new momentum), India's primary energy consumption will more than double by 2050, with an average growth of 2.5%-2.7% per year (BP 2022). Furthermore, India's energy consumption is driven by fossil fuels, primarily coal and oil (Figure 1). India is promoting renewable and alternative energy sources, such as solar and hydrogen, to diversify its energy sources. However, despite these efforts, it is projected that fossil fuels will continue to dominate energy consumption in the coming decades, especially to meet the demand for electricity from the steel, cement, and other coal-consuming industries (Malyan and Chaturvedi 2021).

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For India to reach carbon neutrality would be possible only if the country transitioned from fossil fuel-based power plants and decarbonized its transportation sector. Transitioning to an electricity grid based on renewable energy (RE) is limited by current technological advances. In this context, the role of carbon capture, utilization, and storage is even more crucial for sustainable development in India.

CCUS in India: Initiatives Gathering Momentum

In 2022, the government of India announced its draft road map for CCUS for upstream exploration and production companies. In the proposed road map, the government emphasized the importance of CCUS technology to meet its NZE and nationally determined contribution (NDC) targets, with a focus on technology for enhanced oil recovery from mature oil fields and on the production of chemicals and fuels (Ministry of Petroleum and Natural Gas 2022).

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However, India has been working toward a CCE, and understanding circularity is not new to its energy and climate policy space. In 2003, India became a founding member of the Carbon Sequestration Leadership Forum (CSLF), launched by the US Department of Energy (CSLF 2020). In 2007, India established the Indian CO_2 Sequestration Applied Research (ICOSAR) Network to initiate and facilitate a research dialogue on carbon capture and sequestration applications among stakeholders (Malyan and Chaturvedi 2021). In 2008, the government of India in its National Action

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[2] The Stated Policies Scenario (STEPS) provides a balanced assessment of the direction in which India's energy system is heading based on present-day policy settings and constraints and the assumption that the spread of COVID-19 is largely brought under control in 2021.

Plan on Climate Change (NAPCC) emphasized the use of carbon capture and storage (CCS) technology to reduce emissions from coal-fired power plants (Malyan and Chaturvedi 2021). However, India's initial push toward CCS/CCUS technology failed to gain momentum in the climate policy landscape due to its lack of financial applicability in India's economic growth. In 2015, India became part of the Carbon Capture Innovation Challenge under Mission Innovation (MI) and reinitiated a focus on CCUS research. In 2018, the Indian Department of Science and Technology (DST) and Department of Biotechnology (DBT) jointly commenced research and development (R&D) with other MI member countries to identify and prioritize breakthrough technologies in the field of carbon capture, separation, storage, and carbon added value. Under the Carbon Capture Innovation Challenge (MI-IC3) action plan, India offered twenty proposals for support. Since becoming a member of MI, India has also been an active contributor to the MI initiative (Department of Science and Technology 2022). In 2018, India identified CCUS as a priority area in its Second Biennial Update Report submitted to the United Nations Framework Convention on Climate Change (UNFCCC) (Ministry of Environment, Forest and Climate Change 2018).

In 2021, to strengthen its collaboration with other MI countries, India joined other MI members in launching MI 2.0[3] and initiated a decade of clean energy innovation to accelerate the achievement of the Paris Agreement goals. During the launch of MI 2.0, India launched the MI Cleantech Exchange, which would create a network of incubators across member countries to provide access to the expertise and market insights needed to support new technologies and to access new global markets (Mission Innovation 2021). Furthermore, to cement its position on CCUS, India engaged in a dialogue about participating in the multilateral Accelerating CCUS Technologies (ACT) platform through which avenues have been generated for possible US-India collaboration and collaboration with other

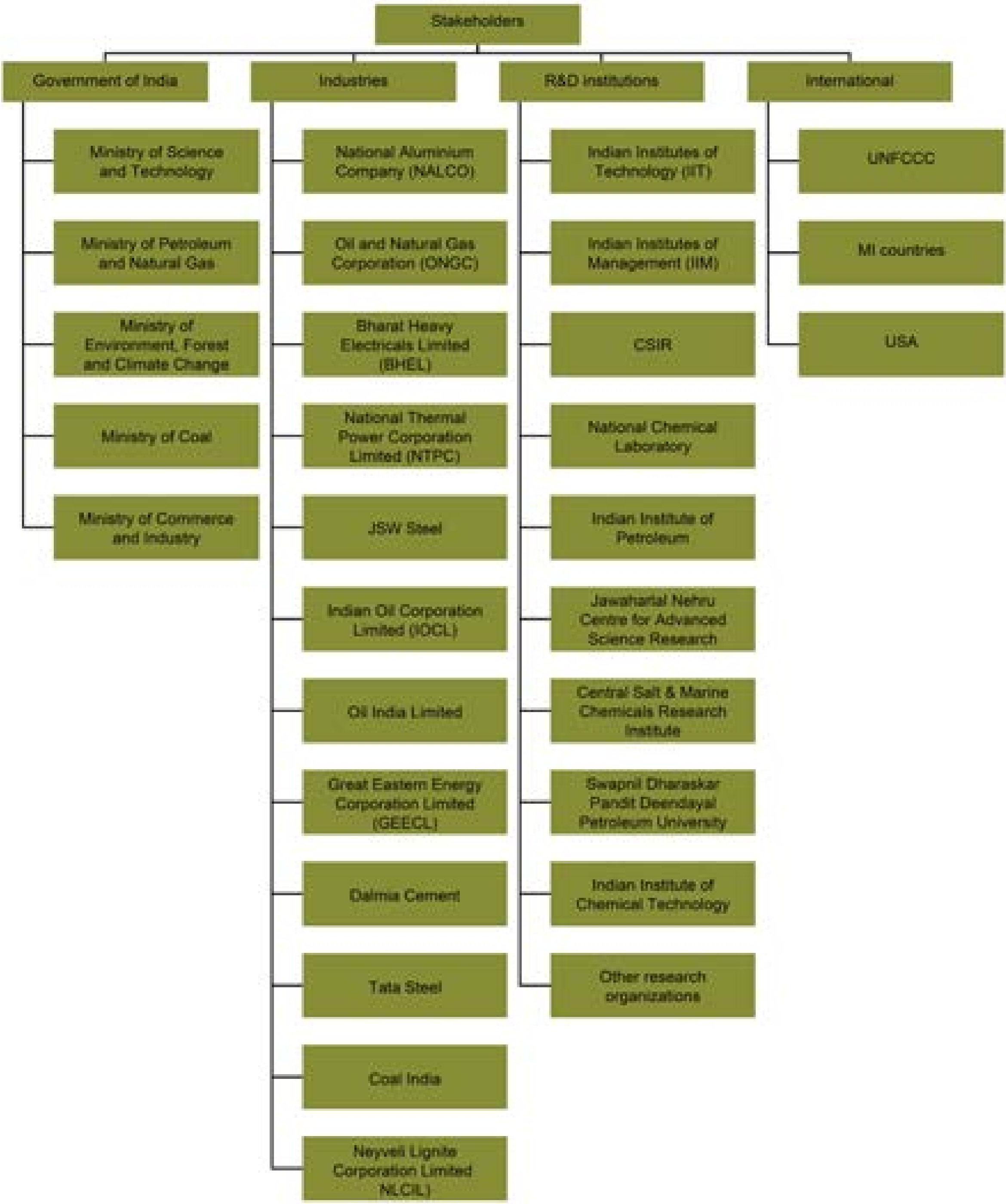
Figure 3. Indian initiatives for CCUS until September 2022

Source: Authors' compilation.

[3] Mission Innovation 2.0, launched on June 2, 2021, is catalyzing a decade of action and investment in research, development and demonstration to make clean energy affordable, attractive and accessible for all.

member countries. In its Third Biennial Update Report to the UNFCCC, India also emphasized the aspiration to disseminate CCUS technology, especially CCUS project uptake in the iron and steel and cement industries (Ministry of Environment, Forest and Climate Change 2021).

Figure 4. Stakeholders involved in policymaking, project dissemination, and R&D activities for CCUS



Sources: Ministry of Petroleum and Natural Gas, Government of India.

In 2018, the Indian DST launched a call for projects for joint R&D with other MI member countries to identify breakthrough CCUS technologies (see Appendix 1).

After becoming part of MI, India pushed for additional support for CCS R&D efforts. However, there were concerns over CCUS uptake due to worries about geological CO_2 storage, high costs, and technological uncertainties. Despite this skepticism, several companies have shown interest in CCUS R&D through project dissemination. A selected list of the research and technological developments in India for CCUS research is highlighted in Table 1.

Table 1. List of projects in India.

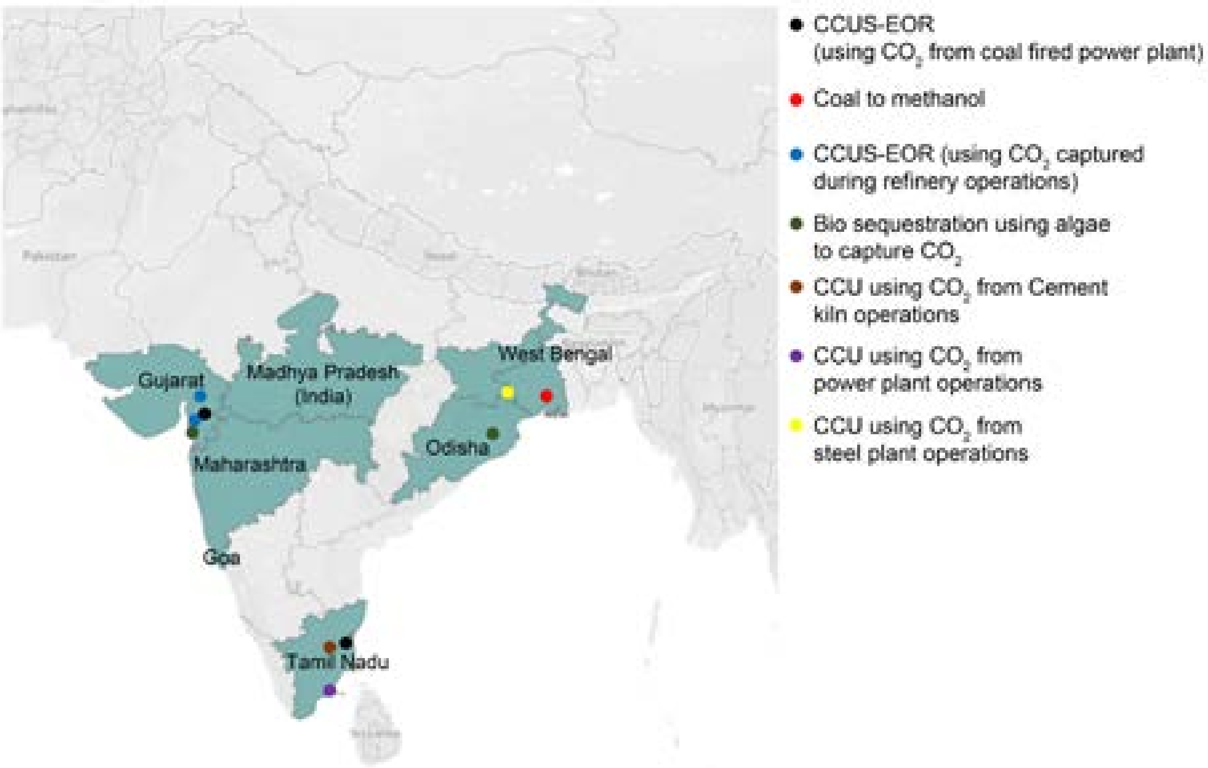
Project	Location	Stakeholders	Reference
Establishment of an enhanced oil recovery (EOR) project to increase crude oil extraction from the Ankleshwar oil field, Gujarat. The plan was to transport CO_2 from the processing plant to the depleted onshore reserve of Ankleshwar to enhance oil recovery	Gujarat	Oil and Natural Gas Commission (ONGC)	(Shaw and Mukherjee)
A pilot reactor was set up at the Hazira processing plant to use captured CO_2 for microalgal growth, which was later used for the production of biogas.	Gujarat	ONGC	(Yadav et al. 2016)
Ultra-supercritical technology for thermal power plants	Jharkhand	Department of Atomic Energy (DAE), Bharat Heavy Electrical Limited (BHEL), National Thermal Power Corporation (NTPC), and Indira Gandhi Centre for Atomic Research (IGCAR)	(Shaw and Mukherjee)
Feasibility study of Indian unminable coal seams for sequestration through enhanced coal bed methane recovery (ECBMR)	Tamil Nadu	Coal India Limited (CIL) and the Geological Survey of India (GSI)	(Shaw and Mukherjee)
Feasibility study for Deccan Traps basaltic rocks as carbon sequestration	Goa, Gujarat and Maharashtra	NTPC, National Geophysical Research Institute (NGRI) and Battelle Pacific North-West National Laboratory, USA	(Shaw and Mukherjee)
Adsorbents aimed at postcombustion capture for CO_2	Pan-India	Indian Institute of Technology—Mumbai, Indian Institute of Petroleum (IIP), Central Salt and Marine Chemicals Research Institute (CSMCRI), and National Environmental Engineering Research Institute (NEERI)	(Shaw and Mukherjee)

Project	Location	Stakeholders	Reference
Biosequestration with a coal-powered plant	Odisha	National Aluminium Corporation (NALCO) and Indo-Can Technology Solutions (ICTS)	(Shaw and Mukherjee)
Integrated gasification combined cycle (IGCC) power plant to implement the prospects of precombustion capture technologies	Tamil Nadu	BHEL	(Shaw and Mukherjee)
Project to convert CO_2 into baking soda	Tamil Nadu	CarbonClean	(Harrabin 2017)
Biomarker algal immobilization technique for accelerating absorption	Pan-India	Neyveli Lignite Corporation Limited (NLCIL) and Pondicherry Engineering College	(Shaw and Mukherjee)
Demonstration project of a 10-MW CO_2 capture plant	Gujarat	NTPC Energy Technology Research Alliance (NETRA) and ONGC	(Shaw and Mukherjee)
Capturing CO_2 from the Cuddalore coal-fired power plant, India, and using it for EOR in oil fields in Kamalapuram and other oil fields in the Cauvery basin, India.	Tamil Nadu	Tamil Nadu Power Company Limited (ITPCL)	(DST)
Implementation of CCUS at the Koyali Refinery in Gujarat to reduce carbon emissions	Gujarat	ONGC and Indian Oil Corporation Limited (IOC)	(Business Standard)
CCUS feasibility study at the Koyali refinery, making it India's largest CCUS project.	Gujarat	IOC and USA-based Dastur International, Air Liquide, and University of Texas	(Shaw and Mukherjee)
Set up a coal-to-methanol plant	West Bengal	Coal-India	(Vishal et al. 2021)
Large-scale carbon capture unit (CCU), a 500,000 tons per year carbon capture facility, the first of its kind in the world.	Tamil Nadu	Dalmia Cement and UK-based Carbon Clean Solutions Limited (CCSL)	(Shaw and Mukherjee)
Hisarna project, a CCU technology, with the support of the European Union to structurally reduce CO_2 emissions	Netherlands	Tata Steel	(Tata Steel)
India's first plant for CO_2 capture from blast furnace gas. A 5 tons per day carbon capture plant, the first of its kind in the world within the steel industry	Jharkhand	Tata Steel	(Tata Steel 2021)

The table represents the most promising projects and R&D in India. However, there are many other projects that are not listed here

Sources: See table.

Figure 5. Indicative CCUS research and technological developments in India



Source: Authors' compilation based on multiple sources.

All the projects discussed above showcase the Indian government's and stakeholders' aspirations toward CCUS technologies. However, these research and development projects and initiatives must translate into a developed ecosystem to support CCUS in the Indian market. Success will depend not only on technology dissemination, which is expected to become cheaper and more viable in the future, but also on government policies to encourage CCUS. The government of India has already initiated one such policy initiative through its "Draft 2030 Roadmap for Carbon Capture Utilization and Storage (CCUS) for Upstream E&P Companies," which provides guidelines for the dissemination of CCUS technologies for upstream oil exploration and production companies. The road map has already identified prospective fields for CO_2-EOR as CCUS, identifying a total of 14 reservoirs under the ONGC portfolio and 23 under Oil India limited. The following future initiatives are also recommended under the CCUS road map:

- Short term (0–3 years)
    - Establish targets as per the NZE-2070 goal
    - Include CCS/CCUS in the National Climate Action Plan

Success will depend not only on technology dissemination, which is expected to become cheaper and more viable in the future, but also on government policies to encourage CCUS

    - Create favorable conditions for investment
    - Provide financial support for feasibility studies for early-mover projects
    - Provide viability gap funding (VGF) for commercial projects at concessional rates
    - Establish and propagate carbon markets
    - Provide tax credits to CCUS/CCS equipment owners
    - Provide funding to support capital and operating costs for early projects
    - Develop a geological CO_2 storage atlas
    - Further encourage and augment R&D
    - Set up a robust and transparent support system
- Medium term (3–10 years)
    - Allocate risks across the public and private sectors
    - Target industrial hubs with shared CO_2 infrastructure
    - Establish a legal and regulatory framework for safe and secure storage
    - Identify and encourage the development of CO_2 storage
    - Support public awareness and education
- Long term (10–15 years)
    - Encourage technology innovation to reduce capture costs and support novel technologies through R&D
    - Develop India as a CO_2 storage hub
    - Create a dedicated workforce for CCUS/CCS

In addition to policy initiatives and R&D projects, India is seeking global technological assistance for its industrial sector to reduce rising emissions. In September 2022, the Ministry of Petroleum and Natural Gas invited expressions of interest (EOIs) from Indian and global companies for carbon capture technology for furnace stack gases used in combustion plants to enable fossil fuel-based heavy industries to capture CO_2 at the source and inject it into geological reservoirs or convert it into fertilizers for industrial use (News 18 2022).

Conclusion

The commentary broadly reviewed the current CCUS scenario and prospects in India. The projects discussed here hold significant promise, although some are still in the experimentation stage. These projects could complement each other in addressing the issue of CCUS in India. However, moving forward with the right policy framework to encourage public-private partnerships could provide an impetus for CCUS technology in India. The next decade or so could be crucial for the development of CCUS in India. With the right initiatives, policy, and technical framework, India could position itself as a leading country on the carbon reduction map. Furthermore, these efforts will move India one step closer to its NZE goal by the year 2070.

With the right initiatives, policy, and technical framework, India could position itself as a leading country on the carbon reduction map

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Appendix 1

Table 2. List of projects supported under Mission Innovation by DST-CCUS during FY 2019–20.

S. no.	Project	Funding in millions of USD
1	Hierarchical porous covalent organic nanosheets and nanosheet-based hybrid membranes for carbon capture and CO_2 separation	0.08
2	Development of methods for utilization and conversion of waste CO_2 to fuels	0.09
3	Demonstration of 10,000 lit/day syngas generation	0.10
4	Development of integrated technologies for the reduction of anthropogenic/industrial waste CO_2 to value-added chemicals and fuels	0.46
5	A systematic large-scale assessment for potential of CO_2-enhanced oil and natural gas recovery in key sedimentary basins in India	0.28
6	Development of a hierarchical novel catalyst for one-pot conversion of CO_2-rich synthesis gas to dimethyl ether and scale-up studies	0.24
7	Adsorption and separation of CO_2 by porous carbon obtained from agricultural residues and advanced microporous materials through cost-effective, clean energy methodology	0.18
8	Integrated CO_2 absorption and conversion to methanol in slurry phase reactors using metal complexes as catalyst	0.13
9	Development of hybrid multielectrode plasma reactor for energy-efficient dry reforming of greenhouse gases	0.11
10	Structure, interaction and process for energy-efficient CO_2 separation using novel ionic liquids supported membranes	0.04
11	Study on new green CO_2-capturing solvents	0.06
12	Model-based design, synthesis and evaluation of combined sorbent catalyst material (CSCM) for CO_2 capture	0.15
13	Nano-engineered inorganic halide perovskites for photo, electro and thermochemical (PETC) CO_2 reduction: Novel artificial photosynthesis implementation for clean energy generation	0.03
14	Development of catalysts and a prototype device for conversion of CO_2 to fuels/chemicals	0.07
15	Development of low-cost, efficient and scalable materials for CO_2 capture using naturally available nontoxic stable materials and industrial solid wastes	0.09
16	Demonstration of a novel concept for converting solar energy into chemical energy	0.10
17	Studies on CO-fueled self-sustaining unmixed combustion (UMC) reactor for integrated CO_2 capture and power/steam generation	0.06
18	Development of an agromechanical model for CO_2 injection and methane release through experimental studies of matrix shrinkage/swelling, mechanical properties, and permeability of coals	0.07
19	Bench-scale design and development: Investigation of high-frequency, high-intensity ultrasonics for carbon-rich solvent regeneration in solvent-based postcombustion CO_2 capture process (PCCC) for reducing CO_2 capture energy demand	0.30

In India, the financial year (FY) ends on March 31 every year and the new financial year starts on April 1.

Source: Department of Science and Technology, India.

About the Project

As the pace of economic growth in China moderates, India seems to be positioned to become the largest fast-growing economy in the world and is likely to see an increase in its demand for imports of oil and gas. Move toward low-carbon public transport and increasing the pace of smart mobility adoption will influence India's oil demand growth, as will its adherence to its global climate commitments. The objective of this project is to analyze the economic, institutional, and policy determinants of energy demand in India and South Asia as a whole.

KAPSARC is engaged in understanding the primary catalysts for India's changing energy demand and evaluating the significance of its energy policies and security strategies for Saudi Arabia and the global community. The analysis will help provide a more in-depth and comprehensive understanding of domestic Indian energy challenges and policies designed to address these challenges. The research project aims to investigate the global consequences of changes in energy markets within India, thus allowing assessment and analysis of information to obtain policy-relevant insights. In line with KAPSARC's overall objectives, the aim is to assist stakeholders outside India to understand the consequences of decisions made by Indian policymakers.

About KAPSARC

KAPSARC is an advisory think tank within global energy economics and sustainability providing advisory services to entities and authorities in the Saudi energy sector to advance Saudi Arabia's energy sector and inform global policies through evidence-based advice and applied research.

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