INTERNATIONAL JOURNAL FOR LEGAL RESEARCH AND ANALYSIS

Open Access, Refereed Journal Multi Disciplinary
Peer Reviewed

www.ijlra.com

 ISSN: 2582-6433

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 ISSN: 2582-6433

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ISSN: 2582-6433

CARBON CAPTURE AND STORAGE (CCS) AS A KEY ENABLER IN ACHIEVING NET ZERO: EXPLORING THE ROLE OF CCS IN INDIAN CONTEXT

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Abstract

Climate change, driven by greenhouse gas emissions from the energy sector, poses a significant global challenge. The Paris Agreement sets ambitious targets to limit temperature rise, necessitating low-carbon technologies like Carbon Capture, Utilization, and Storage (CCUS), particularly for hard-to-abate sectors such as cement, steel, and petrochemicals. This research explores CCUS's role in supporting India's climate goals, emphasizing the need for a comprehensive policy framework and public-private partnerships to overcome deployment barriers. Despite CCUS's potential, its adoption in India is hindered by high costs, technological limitations, and the absence of a regulatory framework. Through a review of global and Indian literature, policy documents, and case studies, this study assesses India's CCUS initiatives and identifies pathways for progress. Key findings highlight India's commitments under the Paris Agreement, including its net-zero target by 2070, and early CCUS efforts, such as collaborations between ONGC and IOCL and Dalmia Cement's planned 500,000-tonne carbon capture plant in Tamil Nadu. However, scaling these efforts requires addressing policy gaps and economic challenges. The research suggests that a public-private partnership model, supported by domestic and international financial assistance, could enable initial CCUS projects until they become economically viable. A robust legislative framework, incorporating incentives and carbon markets, is essential for widespread adoption. International cooperation, including technology transfers from developed nations, could further accelerate India's progress. This study underscores CCUS's critical role in achieving sustainable development and net-zero emissions, offering actionable insights for policymakers and industry stakeholders.

***Keywords**: Climate Change, Paris Agreement, Carbon Capture Utilization and Storage (CCUS), India, Net-Zero Emissions, Policy Framework, Public-Private Partnership.*

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1. Introduction

The entire world is witnessing the problem of climate change. Climate change refers to the long-term shifts in the temperature and weather patterns which occurs due to both natural and man-made activities.[1] It has been observed that anthropogenic activities have been the largest contributor of climate change since the industrial revolution.[2] Burning of fossil fuels like coal, oil and natural gas are the main drivers of climate change. Burning of these fuels results into the emission of greenhouse gases. Carbon dioxide and methane are the primary greenhouse gases responsible for climate change. Carbon emissions traps heat in the atmosphere and results in climate change. Temperature rise is not the only cause of climate change, instead it is just the beginning. As earth is a system where everything is connected, changes in one area leads to changes in others. Intense droughts, severe fires, water scarcity, rise in sea levels, floods, melting of polar ice, decline in biodiversity and catastrophic storms are all consequences of climate change.[3] Top 10 countries which are the highest emitters contributes to 68 percent while 100 least emitting countries generate 3 percent of the total emissions that causes climate change.[4] Sustainable development Goal No. 13 i.e., Climate action deals with taking urgent actions in order to combat the climate change. Energy transition towards low carbon fuels has been taking place by replacing conventional fuels like coal, oil and natural gas. The Paris Agreement has set the limit below 2°C and preferably 1.5°C below which cannot be achieved unless cutting down emissions resulting from anthropogenic activities. Some of the hard-to-abate sectors like steel, cement, chemicals, shipping, aviation and heavy transportation mainly relies on fossil fuels for meeting their energy demands.[5] Energy generation using renewable energy sources has been identified as a suitable option to achieve decarbonization as these alternatives energy sources are cleaner and does not result in the emission of greenhouse gases like CO_2. Low carbon technologies can be instrumental in meeting the energy demands of the energy sector provided global efforts are made in order to implement these technologies which requires global efforts. The developed nations in accordance with best available science develop these technologies and provide financial

[1] United Nations, 'What Is Climate Change?' (United Nations) https://www.un.org/en/climatechange/what-is-climate-change accessed 22 March 2023.
[2] National Academy of Sciences, *Climate Change: Evidence and Causes: Update 2020* (The National Academies Press 2020) 5
[3] United Nations (n 1)
[4] M Ge, J Friedrich and L Vigna, '4 Charts Explain Greenhouse Gas Emissions by Countries and Sectors' (World Resources Institute, 6 February 2020) https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors accessed 22 March 2023
[5] Victor Tachev, 'COP26 and the Future of Hard-to-Abate Sectors in Asia' (Energy Tracker Asia, 12 November 2021) https://energytracker.asia/cop26-and-hard-to-abate-sectors/ accessed 22 March 2023

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assistance to the developing countries in order to achieve its climate change targets. The parties to the Paris Agreement are required to submit their Nationally Determined Contributions where the parties through their domestic efforts achieve their net zero targets in accordance with the agreement. NDCs embodies efforts made by each country to reduce emissions and adapt to the impacts of the climate change.[6] In order to achieve net zero targets, negative emission technologies are required to be deployed on a large scale. CCS is one of the negative emission technologies (NET) which extract CO_2 from the point sources or atmosphere, stores and utilizes them. In various negative emission technologies like DACCS, BECCS in which CCS is a critical component. Ultimately these technologies remove CO_2 from the atmosphere which is primarily responsible for causing global warming and leading to climate change.[7] CCUS is an emerging technology that involves capturing CO_2 emissions from industrial processes or powerplants, and storing it in geological formations or utilizing it in other applications.[8]

CCS technologies are required to be developed and deployed throughout the world in order to curb the catastrophic threats of climate change. Developing countries like China, India and Russia are one of the largest emitters of CO_2 and also developed country like USA is the second largest emitter of CO_2 only after China.[9] The Intergovernmental Panel on Climate Change (IPCC) emphasized that if we are to achieve the goals of Paris Agreement and limit future temperature increases to 1.5°C we must deploy the technologies to remove carbon from the atmosphere in addition to increasing our efforts to reduce emissions. In order to accomplish the deployment of CCUS various issues are required to be considered to address all aspects of the CCUS value chain with a strong focus on how frameworks function to ensure the safe and secure storage of CO_2. Oil and gas industry frameworks, safety and waste management and environment protection frameworks can collaboratively lead to the development of comprehensive framework for CCUS.

[6] Paris Agreement (adopted 12 December 2015, entered into force 4 November 2016) 3156 UNTS 79, art 4
[7] IEA, *Carbon Capture, Utilisation and Storage* (IEA 2022) https://www.iea.org/reports/carbon-capture-utilisation-and-storage-2 accessed 22 March 2023
[8] Esin Serin, 'What is carbon capture, usage and storage (CCUS) and what role can it play in tackling climate change?' (Grantham Research Institute on Climate Change and the Environment, March 2023) https://www.lse.ac.uk/granthaminstitute/explainers/what-is-carbon-capture-and-storage-and-what-role-can-it-play-in-tackling-climate-change/ accessed 22 March 2023
[9]Andriy Blokhin and others, 'The 5 Countries That Produce the Most Carbon Dioxide (CO2)' (Investopedia, 10 October 2022) https://www.investopedia.com/articles/investing/092915/5-countries-produce-most-carbon-dioxide-co2.asp accessed 22 March 2023

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2. Paris Agreement and Global Energy Sector

Every five years, nations that have signed the Paris Agreement submit their Nationally Determined Contributions ('NDCs') to the UNFCCC secretariat. The parties outline their goals for reducing emissions, as well as preparations for adapting to climate consequences and the financial needs for their execution. NDCs are revised every five years and represent a country's intention to meet climate goals. The NDCs are developed independently by countries and are based on achieving net zero emissions by 2050, limiting global temperature rise to well below 2 degrees Celsius and pursuing efforts to limit it to 1.5 degrees Celsius, reducing greenhouse gas emissions, increasing adaptation to the harmful effects of climate change, and adjusting financial flows so that they can be combined with reduced greenhouse gas emissions. Climate adaptation and resilience are the key elements of the Paris Agreement.

The 2022 United Nations Climate Change Conference (COP27) was held from November 6-20 at Sharm el-Sheikh in Egypt. It ended with an agreement to give loss and damage funding to vulnerable nations severely impacted by floods, droughts, and other climate catastrophes. It was a historic decision since it was the first-time nations decided to create a fund and the required funding arrangements to address the loss and damage caused by climate change's devastating impacts. A "transitional committee" will give suggestions on how to operationalize the new funding system and fund for discussion and acceptance at COP28, which will be convened in November 2023 at Expo City Dubai. Countries pledged again at COP 27 to keep global warming at 1.5 degrees Celsius above pre-industrial levels. A mitigation work plan was formed in Sharm el-Sheikh which aimed at swiftly ramping up mitigation ambition and execution. The mitigation plan will begin right away and last until 2026, at which point it will be reviewed to see whether it should be extended. The Paris Agreement Global Stockdale evaluates the global reaction to the climate problem over the course of two years. The second technical session of the first Global Stockdale took place at COP27 when governments and non-party stakeholders get together to discuss where they are collectively making progress towards fulfilling the objectives of the Paris agreement and where they are not. During COP28, the main results of the first Stockdale process will be summarized and presented, and their implications will be reviewed and taken into account, leading to more robust and ambitious climate policies from national governments. Finance is at the centre of everything being done to prevent climate change. Mitigation, adaptation, loss and damage, and climate technologies all need enough funding to work efficiently and provide the intended effects. The Sharm el-Sheikh Implementation Plan, which was adopted at COP27, emphasises that the global

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transition to a low carbon economy is anticipated to need investments of at least USD 4-6 trillion year. The latest pledges to the Adaptation Fund, Least Developed Countries Fund, and Special Climate Fund were welcomed by all countries.

Since, energy sector is primarily responsible for the emissions of greenhouse gases and thereby causing the climate change. Energy sector requires an energy transition in order to achieve these climate change targets set under the Paris Agreement. Energy sector heavily relies on fossil fuels like coal, oil and natural gas and reliance on these fuels in the long run triggers climate change. Developed countries like USA, and EU can financially assist the developing countries in fighting climate change by providing finances in order to contribute towards the Nationally Determined Contributions of the developing nations.[10]

Deployment of low carbon technologies and making them commercially available in most of the regions can be instrumental in reducing the emissions in order to achieve net zero targets within the stipulated time frame. Widespread deployment of emerging technologies for keeping emissions in accordance with the international climate goals is possible through combined efforts of both government and private sector in intensified R&D, support for market deployment and providing enabling infrastructure. Countries have made significant investment in the renewable as they are one of the most strongly deployed low carbon options. According to the State of Climate Action report, in order for the world to achieve the emissions reductions necessary by 2030, nations must, among other things, swiftly phase out coal in power production, stop deforestation, boost the use of low-carbon fuels in transportation, and scale up public and private investment.[11] SDG13 is *"Take urgent action to combat climate change and its impacts."* Energy industry can contribute to this SDG by way of decarbonizing and improving energy efficiency, reducing the carbon footprint of their products, services and processes and setting ambitious emission reduction targets as well as scaling up investment in the development of innovative low-carbon products and services.

The primary pillars of decarbonizing the global energy system include energy efficiency, behavioural changes, electrification, renewables, hydrogen and hydrogen-based fuels, and

[10]UNFCCC, 'Five Key Takeaways from COP27' (UNFCCC) https://unfccc.int/process-and-meetings/conferences/sharm-el-sheikh-climate-change-conference-november-2022/five-key-takeaways-from-cop27 accessed 22 March 2023
[11] Ge, Friedrich and Vigna (n 4)

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Carbon Capture, Utilisation and Storage ('CCUS').[12]

As CCUS is the negative emission technology it plays a pivotal role in removing CO_2 from the point sources or from the atmosphere and thus becomes the primary pillar of decarbonization. The production of blue hydrogen from natural gas is supported by CCS or CCUS in order to capture the CO_2 emitted during the production process and this CO_2 is captured, stored or utilized accordingly.

2.1. CCUS and Paris Agreement Targets

The collection, transport, and geological storage of carbon dioxide use a variety of technologies. The bulk of research and development has been focused on enhancing the separation efficiency of CO_2 from other compounds commonly released by industrial processes. These technologies are typically referred to as "capture technologies." There are three kinds of capture processes, with the applicability of each depending on the industrial process or type of power plant in issue.[13]

In the post-combustion process, carbon dioxide is extracted from the flue gas that is produced when a fossil fuel is burned. During the post-combustion separation process, a solvent is used to collect the carbon dioxide (CO_2). Plants that use pulverised coal (PC) and plants that use natural gas combined cycle are two examples of typical uses for this technology (NGCC). This method is especially useful for situations involving retrofitting.[14]

During the pre-combustion phase of the process, the main fuel reacts with steam, air, or oxygen to produce a mixture of carbon monoxide and hydrogen that is often referred to as a "syngas." In a process known as a "shift reactor," the carbon monoxide is ultimately transformed to carbon dioxide. After that, the CO_2 may be separated, and the hydrogen can be put to use in the production of electricity and/or heat. This technique is especially well-suited for use in power plants that use an integrated gasification combined cycle (IGCC).[15]

[12] IEA, *Net Zero by 2050: A Roadmap for the Global Energy Sector* (IEA 2021) https://www.iea.org/reports/net-zero-by-2050 accessed 22 March 2023
[13] CTC-N, 'CO2 Capture Technologies' (CTC-N) https://www.ctc-n.org/technologies/co2-capture-technologies accessed 22 March 2023
[14] ibid
[15] IPCC, *Special Report on Carbon Dioxide Capture and Storage* (B Metz and others eds, Cambridge University Press 2005) 442

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Oxy-fuel combustion is a kind of combustion in which the primary fuel is combusted in oxygen rather than air, which results in the production of flue gas that is mostly composed of water vapour and has a high concentration of carbon dioxide (80%). The flue gas is subsequently cooled, which causes the water vapour to condense and results in a stream of CO_2 that is nearly completely pure. The in-situ synthesis of oxygen from air requires additional equipment.[16]

Various industrial processes including natural gas processing, steel, cement and ammonia production utilizes these separation technologies.[17]

At the 26th session of the Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Glasgow, United Kingdom, the Government of India expressed the concerns of developing countries.[18] Moreover, India put forth the subsequent five essential components (Panchamrit) of India's climate action:

- *"Reach 500GW non-fossil energy capacity by 2030.*
- *50 per cent of its energy requirements from renewable energy by 2030.*
- *Reduction of total projected carbon emissions by one billion tonnes from now to 2030.*
- *Reduction of the carbon intensity of the economy by 45 per cent by 2030, over 2005 levels.*
- *Achieving the target of net zero emissions by 2070."*

These targets can be achieved only after phasing out fossil fuels and deploying low carbon technologies like renewable energy. Carbon-dioxide which is already present in the air can be captured both by natural as well as engineered solution. The negative emission solutions can be classified into engineered solutions and natural solutions. Natural solutions include reforestation and afforestation. Direct Air Capture and Bioenergy with carbon capture and storage (BECCS) can be classified as engineered solutions.

CCUS encompasses a broad variety of CO_2 collection, use, and storage technologies. Large point sources, such as the power sector and industrial facilities employing fossil fuels such as coal, oil, and natural gas, may trap CO_2. This CO_2 may also be extracted from the air using Direct Air Capture technologies. This acquired CO_2 may be compressed and delivered by

[16] ibid
[17] Supra Note 23
[18] PIB, 'India's Stand at COP-26' (Press Information Bureau, 3 February 2022) https://www.pib.gov.in/PressReleasePage.aspx?PRID=1795071 accessed 22 March 2023

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pipeline, ship, or truck for use in a variety of applications, or it can be injected into deep geological formations (such as depleted oil and gas reserves and saline aquifers) where it is trapped and permanently stored.[19] CCUS has four important functions that contribute to emission reductions in practically every aspect of the energy system and facilitate the transition to net-zero CO_2 emissions by tackling the emission from existing energy infrastructure, providing way to tackle emissions from some of the most challenging sectors which are hard to decarbonize known as hard-to-abate sectors, providing an economical way to boost the production of low carbon hydrogen and by allowing CO_2 removal from the atmosphere by utilizing BECCS and DACCS techniques.[20] BECCS involves growing crops, which absorbs CO2 emitted at that source. These plants are then burnt in power stations to generate electricity.

2.2. India and CCUS

The World Economic Forum highlighted that *failure to mitigate climate change and failure to climate change adaptation* tops the rankings of the most severe risks on a worldwide scale.[21] The IPCC report suggests that the probability of breaching the 1.5°C target by as early as 2030 is 50%.[22]

In a developing country like India, deployment of CCUS has been hindered by two factors i.e., absence of policy and regulatory framework and economic and technological limitations in regard to high costs associated with the capture and transport of CO_2.[23]

USA, Canada, UK, Norway, Australia and China are already heading towards development and deployment of a roadmap for CCS/CCUS projects.[24]

Health and education are the fundamental sectors that every country is required to develop. India being a developing country has public health, social welfare and education as priority. Under appropriate circumstances, forming partnerships between the public and private sectors

[19] IEA, *Legal and Regulatory Frameworks for CCUS: An IEA CCUS Handbook* (IEA 2022) 9 https://www.iea.org/reports/legal-and-regulatory-frameworks-for-ccus accessed 22 March 2023
[20] IEA (n 12) 79
[21] World Economic Forum, *Global Risks Report 2023* (18th edn, World Economic Forum 2023)
[22] IPCC, 'Summary for Policymakers' in *Global Warming of 1.5°C: An IPCC Special Report* (V Masson-Delmotte and others eds, Cambridge University Press 2018) 3-24
[23] Ministry of Petroleum and Natural Gas, *Draft 2030 Roadmap for Carbon Capture Utilisation and Storage (CCUS) for Upstream E&P Companies* (2022) https://mopng.gov.in/files/article/articlefiles/Draft_UFCC_Roadmap_2030_v3.pdf accessed 22 March 2023
[24] ibid

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can open up opportunities for additional resources, improved service coverage, and enhanced quality in services.[25] Implementation of CCUS requires a model under public-private partnership with financial support from domestic and as well as global government agencies. This approach can be adopted for initial projects till an economically viable business model is evolved for CCS/CCUS.[26]

India's Second Biennial Update Report, which was submitted to the UNFCCC, designated CCUS as a priority area. The nation actively participates in Mission Innovation's Carbon Capture Innovation Challenge (MI).[27] A global project called Mission Innovation aims to speed up public and private clean energy innovation in order to combat climate change, lower the cost of clean energy for consumers, and generate green employment and business possibilities. India participated actively in the MI Steering Committee and is a part of the subgroups for Joint Research and Business & Investor Engagement.

On the sidelines of Paris Climate Agreement, Mission Innovation was unveiled to carry out the bold actions needed to tackle climate change. This worldwide project to speed up renewable energy innovation has been launched by the European Union and 24 other nations in the year 2015.

Commitment was made by all members with an aim to aim to invest twice as much in clean energy innovation over the course of five years in a few prioritized areas. Each member individually chooses the best use of its resources and establishes its own Research & Development priorities and path to achieve the doubling target in accordance with its own goals, policies, procedures, and regulations. Members of MI frequently priorities certain portions of their whole energy budget within their baseline.

Its goals include raising awareness of the transformative potential of innovation and increasing private sector participation and investment. It also seeks to improve international collaboration.

In order to leverage research, development, and demonstration in technology fields that may ultimately lead to efficient ways to reduce greenhouse gas emissions, increase energy security, and create new opportunities for clean economic growth, innovation challenges play a

[25] Yidan Wang, 'Public-Private Partnerships in the Social Sector' (year) 1
[26] IEA (n 12) 79
[27] Amrita Goldar and Diya Dasgupta, 'Exploring Carbon Capture, Utilisation and Storage in the India Context' (January 2022) 9-10

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significant role in the mission innovation. Under the mission innovation, there are eight innovation challenges: *IC1: smart grids, IC2: Off-grid access to electricity, IC3: Carbon capture, IC4: Sustainable biofuels, IC5: Converting sunlight, IC6: Clean energy materials, IC7: Affordable cooling and heating of buildings, IC8: Renewable and clean hydrogen.*

The government has adopted CCUS quite slowly, mostly due to concerns about geological carbon-dioxide storage, high prices, and uncertainty surrounding such technology. Despite the doubts surrounding CCUS, some independent businesses have entered this market. As an illustration, the ONGC and IOCL signed a Memorandum of Understanding in July 2019 to collaborate on efforts to reduce carbon emissions through the installation of CCUS at the Koyali Refinery in Gujarat.

Similar intentions were made public by Dalmia Cement to build a 5,000-tonne carbon capture cement factory in Tamil Nadu. As of September 2019, a Memorandum of Understanding for technology and operational services for running the plant has been inked with UK-based Carbon Clean Solutions (CCSL). Although there are a few small-scale CCS cement factories in the EU and China, this is the first factory of its sort. Dalmia is the first cement manufacturer in the world that have made the commitment to achieve carbon neutrality by 2040.

Additionally, a factory at the Tuticorin industrial port absorbs carbon dioxide produced by its boiler and utilizes it to make baking soda, which has a large market in sectors including glass manufacturing, detergents, and paper goods. There are also plans for small-scale capture and utilization plants for fertilizers.[28]

3. Conclusion

In order to achieve sustainable development, synergetic actions are required as impact on one area directly or indirectly affects the other. The energy sector which is primarily responsible for causing man-made climate change has various consequences and hence the amount of CO_2 which is released in the atmosphere has to mitigated in order to achieve the goals of Paris Agreement. Hence development of a legislative framework becomes crucial in order to deploy these technologies which is only possible by a private and public partnership and a well-established carbon market. The view points to scientists, economists and policy makers

[28] ibid 9-10

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collaboratively leads to the development and deployment of CCUS in order to achieve net zero targets.

The Prime Minister's pledge at COP26 for a net-zero India by 2070 has expedited India's march towards sustainable energy. In order to fulfil these commitments, substantial steps are required.

Carbon Capture, Utilization, and Storage (CCUS) plays a significant and critical part in India reaching net-zero emissions by 2070. The use of CCUS in the power industry would create sustainable prospects for India's over 70% reliance on coal to satisfy its electricity demands. The CCUS will contribute to the achievement of the objective by providing clean and sustainable baseload electricity and by assuring sustainability. To allow feasible projects across the CCUS value chain and at scale for the key industrial sectors of the Indian economy, including as electricity, steel, cement, and petrochemicals, a solid and effective CCUS policy framework is necessary. Implementation and development of CCS technologies are essential for India's sustainable growth. In India, CCUS cannot become a reality without direct capital grants, tax credits, carbon pricing programmes, operational subsidies, regulatory requirements, and public procurement preference for low-carbon items. Hence in order to achieve net zero targets, a comprehensive legislative framework for CCUS is required.