Introduction

Carbon Dioxide Removal (CDR) is an essential component of global efforts to combat climate change and achieve net-zero targets. As nations strive to balance economic development with environmental sustainability, CDR technologies offer promising solutions. In South Asia, comprising India, Malaysia, and Singapore, the adoption of CDR is critical for mitigating the region's vulnerability to climate change. These nations face challenges such as rapid urbanization, industrialization, and reliance on carbon-intensive industries, making CDR technologies a necessity to offset emissions.

Government initiatives, such as India's carbon trading policies under the Energy Conservation (Amendment) Act, 2022, and Singapore's Green Plan 2030, highlight the growing commitment to CDR (Government of India, 2022; Ministry of Sustainability and the Environment, 2021). Malaysia, through private-sector innovation like Carbon Zero's Bukit Selar Carbon Station, emphasizes sustainable forestry as a carbon sequestration strategy. Despite these advancements, barriers such as high costs, limited public awareness, and fragmented policies remain prevalent.

This paper explores the contributions of eight companies—Varaha, Takachar, Alt Carbon, Matterak Technologies, Circonomy, Carbon Plus, Carbon Zero, and Equatic, which are pioneering CDR initiatives in South Asia. These organizations employ diverse technologies, including biochar production, enhanced mineralization, direct air capture (DAC), and ocean-based carbon removal. By analyzing the enabling policy frameworks, technological advancements, and socio-economic impacts of CDR, this study provides actionable insights into scaling these efforts across the region.

Theoretical Framework & Methodology

This study employs Stakeholder Theory and Dunning's Eclectic Paradigm as the foundational frameworks to analyze the adoption and scaling of Carbon Dioxide Removal (CDR) technologies in South Asia. These theories provide a robust basis for understanding the socio-economic, policy, and investment dynamics associated with CDR in the region.

Stakeholder Theory, as articulated by Freeman (1984), emphasizes the critical role of diverse stakeholders in achieving organizational or policy objectives. In the context of CDR, this theory offers a lens to examine how governments, private corporations, local communities, and non-governmental organizations (NGOs) collaborate or conflict in their efforts to implement carbon removal projects. By focusing on the interdependence and interests of these actors, Stakeholder Theory provides a structured approach to understanding the social and institutional factors that enable or hinder the success of CDR initiatives. For instance, government regulations, corporate investments, and community engagement play interconnected roles in shaping the outcomes of biochar production or direct air capture projects.

Dunning's Eclectic Paradigm (1977) complements this analysis by focusing on the factors that drive foreign direct investment (FDI) in international business. The paradigm identifies three critical components: ownership, location, and internalization (OLI) advantages. In the context of CDR, the Eclectic Paradigm is particularly relevant for understanding the role of FDI in supporting large-scale carbon removal projects. For example, Singapore's collaboration with Equatic on ocean-based CDR technologies highlights location-specific advantages such as advanced infrastructure, political stability, and strong regulatory support, which attract international investments. This framework underscores how the strategic alignment of ownership resources, locational benefits, and internalization processes facilitates the integration of global expertise into regional CDR strategies.

The methodology employed in this study focuses exclusively on qualitative approaches to ensure a nuanced understanding of the complexities surrounding CDR adoption. A content analysis of policy documents, industry reports, and academic literature provides a comprehensive view of the regulatory

and socio-political frameworks influencing CDR. Additionally, case studies of eight pioneering companies operating in South Asia—such as Varaha, Takachar, and Carbon Zero—offer detailed insights into their technological innovations, community engagement strategies, and scalability. This methodological approach emphasizes the contextual factors driving CDR initiatives while avoiding quantitative modeling, ensuring that the analysis remains accessible and practically oriented for diverse stakeholders.

By combining these theoretical and methodological approaches, the study provides a holistic perspective on the socio-economic and policy dynamics shaping CDR adoption in South Asia, highlighting the critical interplay of local and global forces.

Examples

India: Varaha in India focuses on regenerative agriculture and biochar production, collaborating with over 50,000 farmers. By enhancing rural livelihoods and sequestering carbon, it demonstrates the potential of grassroots solutions for climate mitigation. Takachar, also based in India, has developed portable biomass conversion technology that reduces air pollution from crop residue burning while producing biochar for carbon sequestration. Alt Carbon specializes in enhanced mineralization, utilizing silicate rock to accelerate natural weathering for scalable and long-term CO_2 removal. Matterak Technologies designs modular Direct Air Capture (DAC) systems tailored to South Asia's diverse conditions, emphasizing scalability and cost efficiency.

Malaysia: Circonomy works with farmers to convert agricultural waste into biochar, reducing emissions from open burning and improving soil fertility through a circular economy model. Carbon Plus employs biomass gasification to produce biochar and bio-oil, supporting both agricultural sustainability and industrial carbon removal in India. In Malaysia, Carbon Zero's Bukit Selar Carbon Station integrates bamboo cultivation with biochar production, showcasing sustainable forestry practices for carbon removal.

Singapore: Equatic, in partnership with Singapore's PUB, is developing the largest ocean-based CDR facility, projected to remove 3,650 tonnes of CO_2 annually by 2025. These examples illustrate diverse, innovative approaches to CDR in South Asia, integrating technological advancement with socio-economic benefits to address regional climate challenges.

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