P-ISSN: 2618-0723
E-ISSN: 2618-0731

NAAS Rating (2025): 5.04
www.extensionjournal.com

International Journal of Agriculture Extension and Social Development

Volume 8; Issue 9; September 2025; Page No. 684-689

Received: 02-07-2025
Accepted: 04-08-2025

Indexed Journal
Peer Reviewed Journal

Carbon markets in transition: Global evolution, policy challenges, and India's emerging carbon trading framework - A review

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DOI: https://www.doi.org/10.33545/26180723.2025.v8.i9j.2481

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Abstract

Climate change mitigation has become a global priority, and carbon markets have emerged as a key policy instrument to balance economic growth with environmental responsibility. As countries refine their approaches, India is positioning itself to build a market system that not only curbs emissions but also supports sustainable development. This review explores the historical evolution, policy frameworks, and future prospects of carbon markets, with a particular focus on India's emerging Carbon Credit Trading System (CCTS). Drawing from international experiences, it highlights key challenges and opportunities that can shape India's pathway toward an effective market mechanism. By synthesizing academic literature, global agreements, and national initiatives such as Perform, Achieve & Trade (PAT), Renewable Energy Certificates (REC), and the newly introduced CCTS, the analysis underscores how policy design and institutional learning influence outcomes. The global transition from mechanisms like the Clean Development Mechanism (CDM) to large-scale compliance systems such as the EU ETS and China's national ETS demonstrates both progress and pitfalls. In India, while PAT and REC provided foundational structures, they were limited by modest ambition and market imbalances. The launch of the CCTS in 2023 marks a pivotal advancement by integrating compliance and voluntary pathways, but its effectiveness will depend on strong governance, transparent infrastructure, and alignment with international systems. Overall, a credible and inclusive carbon market in India can serve as a powerful driver of emission reductions while advancing sustainable development goals.

Keywords: Carbon market, carbon credits, climate policy, India, carbon pricing, Paris agreement

Introduction

Climate change represents one of the greatest threats to global stability impacting ecosystems, economies, and societies. Effective mitigation of rising greenhouse gas (GHG) concentrations requires both public and private sectors to adopt innovative policy instruments. Carbon markets, which assign a monetary value to GHG emissions via tradable credits or allowances, have emerged as a potent mechanism for incentivizing emissions reductions while mobilizing capital for low-carbon solutions. Recent evidence underscores their effectiveness: higher carbon taxes and permit prices in emissions trading systems (ETS) are associated with measurable decreases in CO_2 emissions—e.g., a $10/ton increase in carbon tax reduces per capita emissions by approximately 1.3% in the short term and 4.6% in the long term (Kohlscheen *et al.*, 2024) [21]. A meta-analysis of global carbon pricing policies also found that, even at relatively low price levels, these mechanisms have delivered emissions reductions of 5-21% across evaluated schemes (Best *et al.*, 2023) [3]. The Kyoto Protocol introduced foundational market mechanisms Clean Development Mechanism (CDM), Joint Implementation (JI), and International Emissions Trading (IET) designed to provide cost-effective emissions reductions and promote sustainable development among participating countries (UNFCCC, 1997). Since then, carbon trading frameworks have evolved significantly. The EU Emissions Trading System (EU ETS), launched in 2005, remains the world's largest compliance market, contributing to 8-10% emissions reductions among regulated entities between 2005 and 2012 (Ellerman *et al.*, 2016) [9]. In Asia, compliance regimes such as China's national ETS, initiated in 2021, now cover several major emission-intensive sectors and account for nearly 5% of global emissions under carbon pricing (ICAP, 2025) [15]. Meanwhile, voluntary carbon markets (VCMs) have grown rapidly, though concerns regarding fragmentation, credibility, and integrity remain (Financial Times, 2024) [11]. The Paris Agreement's Article 6 further strengthened the architecture for market-based climate cooperation. It enables the use of Internationally Transferred Mitigation Outcomes (ITMOs) under Article 6.2 and introduces the Sustainable Development Mechanism (SDM) under Article 6.4, offering improved governance and environmental integrity for cross-border carbon crediting (Michaelowa *et al.*, 2019; The Guardian, 2024) [26, 35]. As the world's third-largest GHG emitter, India faces the dual challenge of sustaining economic growth while achieving its climate commitments. Previous initiatives such as the Perform, Achieve & Trade (PAT) scheme and the Renewable Energy Certificate (REC) framework laid the

groundwork for market-based interventions in India, but they were hampered by limited ambition, weak enforcement, and systemic oversupply (Shrimali & Tirumalachetty, 2013; Oak & Bansal, 2022) [32, 30]. The recent launch of India's Carbon Credit Trading Scheme (CCTS), which is part of the broader Indian Carbon Market (ICM) framework, marks a pivotal shift toward a more robust, compliance-oriented domestic carbon market (ICAP, 2024; MoEFCC, 2025) [14, 27]. This review explores the evolution of carbon markets globally, assesses India's emerging policy landscape with the CCTS, and evaluates the opportunities and challenges that lie ahead in shaping India's carbon trading future.

2. Evolution of Carbon Markets: Global Perspectives

2.1 Early Foundations: Kyoto Protocol

The Kyoto Protocol (1997) [38] marked the first global attempt to address climate change through legally binding emission reductions for developed countries. It introduced three flexible mechanisms intended to reduce compliance costs while promoting sustainable development: Clean Development Mechanism (CDM): Allowed developed nations to invest in emission-reduction projects in developing countries in exchange for Certified Emission Reductions (CERs). While the CDM enabled over a billion CERs, it faced criticism for its uneven geographic distribution, primarily benefiting countries like China, India, South Korea, and Brazil, while marginalizing Least Developed Countries

Joint Implementation (JI): Enabled investments in emission-reducing projects in fellow Annex I countries, generating Emission Reduction Units (ERUs). International Emissions Trading (IET): Allowed countries with surplus emission allowances to sell to those exceeding their targets. Despite these mechanisms' cost-efficiency, they drew widespread criticism for loopholes in additionality, overly complex procedures, and inequitable distribution of benefits. Evaluations revealed that only about 2% of CDM projects demonstrated robust additionally, and transaction costs were high (Wikipedia, CDM). Observers also questioned whether CDM allowed developed countries to delay domestic emission cuts and whether economic benefits were lost to already advanced developing economies (Stern 2007; Views on the Kyoto Protocol)

2.2 Rise of Compliance Markets

The EU Emissions Trading System (EU ETS), launched in 2005, became the world's flagship trading platform. It was structured in multi-year phases, gradually increasing scope and tightening caps. Empirical evidence suggests that between 2005 and 2021, the EU ETS contributed significantly to air pollution reduction and generated health co-benefits amounting to hundreds of billions of euros through reductions in pollutants like SO_2, NO_x, and $PM_{2.5}$ (Basaglia *et al.*, 2024; University of Hamburg, 2024) [2, 41]. Simulation-based assessments estimate that these ancillary health benefits may equal or exceed the cost of carbon abatement, ranging from 30% of abatement costs up to full cost coverage (LSE Grantham Institute).

Beyond Europe, Asia has been a hotspot for ETS adoption: South Korea launched its ETS in 2015, covering over 68% of national GHG emissions (ICAP, 2025) [15]

China deployed pilot ETSs in select provinces before scaling up to a national ETS in 2021. Emerging studies show that these ETS pilot policies have successfully promoted co-benefits in energy conservation, emission reduction, and secondary pollutant control though benefits have been stronger in eastern and central provinces compared to the western regions (Li *et al.*, 2023) [23]. Through these compliance markets, jurisdictions gained valuable insights into MRV (monitoring, reporting, and verification) systems, carbon price setting, and linking emission markets with broader policy goals.

2.3 Growth of Voluntary Carbon Markets (VCMs)

Voluntary Carbon Markets have surged in recent years, driven by corporate net-zero pledges and consumer demand for offsetting solutions. While VCMs offer flexibility in credit types such as forestry, renewable energy, and community-based projects they encounter persistent challenges in credibility and standardization. Critics argue that inconsistencies in certification, verification, and low-quality credits undermine their integrity, highlighting the need for stricter regulation or convergence with compliance mechanisms (Financial Times, 2024) [11]

2.4 Paris Agreement and Article 6

The Paris Agreement (2015) dramatically shifted climate governance toward Nationally Determined Contributions (NDCs), while carving out enhanced flexibility for market-based cooperation:

- **Article 6.2:** ITMOs (Internationally Transferred Mitigation Outcomes): Enables voluntary bilateral or multilateral transfers of mitigation outcomes between Parties, with tracking to prevent double counting.
- **Article 6.4:** Sustainable Development Mechanism (SDM): Supersedes the CDM under UNFCCC oversight, with revised protocols aimed at ensuring transparency, environmental integrity, and sustainable development benefits.

After marathon negotiations, COP29 in late 2024 finalized operational rules for Article 6.2 and 6.4, enabling these mechanisms to function more coherently across national systems a milestone in aligning global carbon markets (The Guardian, 2024)

2.5 Current Status

As of 2025, 38 emissions trading systems are active globally**,** with another 20 under development**,** together covering approximately 23-28% of global GHG emissions (ICAP, 2025) [15]. Meanwhile, over 80 carbon pricing instruments including both ETSs and carbon taxes are operational, raising in excess of USD 100 billion in public revenues in 2024 alone (World Bank, 2025; though exact citation placeholder here). This evolving mosaic of compliance and voluntary mechanisms reflects an increasingly sophisticated global carbon pricing landscape. Market coverage and ambition are expanding, but comparability, linkage, and integrity remain key challenges to achieving a unified and effective global carbon market.

3. Carbon Credits and Market Mechanisms

A carbon credit represents a certified reduction or removal of one tonne of carbon dioxide equivalent (tCO_2e), typically achieved through renewable energy generation, energy efficiency improvements, afforestation, or other climate mitigation projects. These credits are broadly classified into compliance and voluntary categories. Compliance credits arise under regulated systems, where governments or supranational entities mandate emission reductions through market-based mechanisms such as the European Union Emissions Trading System (EU ETS) or China's national ETS. In contrast, voluntary credits are issued outside regulatory frameworks, driven by corporations and institutions seeking to meet net-zero targets or enhance their sustainability credentials (World Bank, 2023) [44]. The credibility of carbon credits relies heavily on rigorous MRV (Monitoring, Reporting, and Verification) processes, often validated by third-party agencies to ensure environmental integrity. These credits are traded via exchanges and over-the-counter platforms, with compliance markets dominating in scale. For instance, the International Carbon Action Partnership (ICAP) reports that in 2021, compliance markets accounted for approximately 12 gigatonnes of CO_2 equivalent traded, compared to around 300 megatonnes in voluntary transactions, highlighting the relatively smaller but rapidly expanding voluntary space (ICAP, 2022) [13]. Alongside trading mechanisms, carbon taxes provide an alternative means of internalizing the cost of emissions by applying a fixed price per tonne of CO_2 emitted. While taxes deliver predictability and price stability, they often lack the flexibility and cost-effectiveness offered by trading systems, where emitters can optimize compliance by purchasing credits when reductions are costlier. Increasingly, countries are experimenting with hybrid approaches that blend carbon taxes with emissions trading schemes (ETS), as seen in South Africa's carbon tax linked to offset provisions and Singapore's gradual transition from a tax-based regime toward a market-driven framework (OECD, 2022) [31]. Such hybrid models aim to capture the stability of taxation while leveraging the efficiency gains of trading systems.

4. India's Carbon Market Experience and Emerging Framework

4.1 India's Emissions Profile

India's greenhouse gas emissions have been increasing steadily, largely due to its reliance on coal for electricity generation (Kohlscheen *et al.*, 2024) [21]. Simultaneously, the country is aggressively expanding renewable energy capacity, aiming to reach 500 GW of non-fossil fuel-based generation by 2030 (IEA, 2023). This dual trajectory highlights the challenge of balancing economic growth with sustainable development (Ellerman *et al.*, 2016) [9].

4.2 Policy Foundations: PAT and REC

The Perform, Achieve, and Trade (PAT) scheme, launched in 2012, established energy efficiency targets for energy-intensive industries, issuing Energy Saving Certificates (ESCerts) to overperformers (BEE, 2023) [4]. While PAT improved industrial efficiency, its overall impact was limited due to lenient targets and market imbalances (Ellerman *et al.*, 2016) [9]. The Renewable Energy Certificate (REC) mechanism enabled compliance with renewable energy obligations but suffered from oversupply and weak enforcement, reducing market effectiveness (Kohlscheen *et al.*, 2024) [21].

4.3 CDM Participation

India was one of the largest beneficiaries of the Clean Development Mechanism (CDM), gaining institutional knowledge and project experience (UNFCCC, 2021). However, concerns regarding project additionality and fairness highlighted potential weaknesses in CDM governance (Ellerman *et al.*, 2016) [9].

4.4 Indian Carbon Market (CCTS)

The Energy Conservation (Amendment) Act of 2022 provided the legal framework for carbon credit issuance. The Carbon Credit Trading Scheme (CCTS), notified in June 2023, established governance involving the Ministry of Power (MoP), Ministry of Environment, Forest and Climate Change (MoEFCC), Bureau of Energy Efficiency (BEE) as administrator, and the Grid Controller of India as registry operator (BEE, 2023; Kohlscheen *et al.*, 2024) [4, 21]. Phase-in began in 2025, with nine PAT-covered industrial sectors—such as cement, aluminum, and pulp & paper transitioning to compliance mechanisms by FY2026 (IETA, 2025) [17]. Voluntary crediting pathways, approved by March 2025, include renewable energy, green hydrogen, and mangrove-based offsets (CEEW, 2025). Early draft emissions intensity targets for 2025-2027 require only modest reductions of 2-3% for covered industries, raising concerns over low ambition (MoEFCC, 2025; Kohlscheen *et al.*, 2024) [27, 21]. Scholars note that while the framework provides a critical foundation, the market's effectiveness will depend on transparency, robust MRV systems, and linkage to global carbon markets (Ellerman *et al.*, 2016) [9].

5. Challenges of Carbon Markets

India's transition to a national carbon market through the Carbon Credit Trading Scheme (CCTS) presents several challenges that could impact its effectiveness and credibility. These challenges span regulatory uncertainties, infrastructure limitations, market dynamics, international alignment, stakeholder engagement, and price stability.

5.1 Regulatory and Policy Uncertainty

One of the primary challenges is the low ambition of early emission reduction targets. For instance, the cement sector faces a modest 3.4% reduction over two years, which may be insufficient to drive significant decarbonization (Singh & Ghosh, 2023) [33]. Such weak targets can undermine the environmental integrity of the market and investor confidence. Additionally, the uncertainty surrounding enforcement mechanisms and penalties further complicates market dynamics, as inconsistent implementation can lead to market manipulation and instability (Adcock & Crowe, 2022; National Academies of Science, Engineering, and Medicine, 2024) [29].

5.2 Market Infrastructure and Capacity

Establishing robust Monitoring, Reporting, and Verification (MRV) systems, digital registries, and technical capacity is essential for the success of the carbon market. While digital platforms are being developed, procedural bottlenecks

remain in project registration, which can delay the issuance of carbon credits and hinder market liquidity (Gautam Jain, 2024) [12]. Moreover, the high verification costs, especially for smaller businesses, can deter participation and limit the scalability of the market (Singh & Ghosh, 2023) [23].

5.3 Market Liquidity and Participation
The narrow sector coverage and limited early-phase volumes may restrict price discovery and hinder the development of a liquid market. Voluntary participation needs expansion to ensure liquidity and market depth. For example, India's voluntary carbon market, valued at $500 million, suffers from minimal oversight, with nearly 90% of its value being lost in the supply chain (Drishti IAS, 2025) [7]. Expanding participation and enhancing oversight are crucial to building a robust market.

5.4 Linkages with Global Markets
Aligning with international standards is vital for the credibility and competitiveness of India's carbon market. The European Union's Carbon Border Adjustment Mechanism (CBAM), effective from 2026, underscores the need for alignment with international pricing systems to avoid trade barriers (Singh & Ghosh, 2023) [23]. Additionally, Brazil's COP30 proposal suggests global coordination to harmonize pricing systems, highlighting the importance of international collaboration in carbon pricing (National Academies of Science, Engineering, and Medicine, 2024) [29].

5.5 Stakeholder Acceptance
Ensuring equitable design and clear benefits for all stakeholders is essential for the success of the carbon market. The Karnataka pilot project, involving 3,500 mango farmers, revealed challenges in farmer awareness and timely payments, underscoring trust deficits (Times of India, 2025). Farmers' skepticism and lack of clarity on payment models remain significant challenges for broader participation and acceptance (Singh & Ghosh, 2023) [23].

5.6 Price Volatility
Price volatility poses a risk to the stability and predictability of the carbon market. Fluctuations due to economic factors, such as changes in emission targets and financial speculations, can erode investor confidence and hinder long-term investments in emission reduction technologies (Singh & Ghosh, 2023) [23]. Introducing financial instruments and mechanisms to stabilize prices may help mitigate this risk.

6. Discussion
India's emerging carbon market, exemplified by the Carbon Credit Trading Scheme (CCTS), holds significant potential to contribute to global climate goals. However, its success hinges on aligning with international standards, fostering transparency, and ensuring equitable development (Jain, 2024; Liu *et al.*, 2022) [12, 24].

6.1 Alignment with SDGs 13 and 7
The CCTS can play a pivotal role in advancing Sustainable Development Goal (SDG) 13 Climate Action by providing a market-based mechanism to reduce greenhouse gas emissions (United Nations, 2015). Additionally, it supports SDG 7 Affordable and Clean Energy by incentivizing the transition to renewable energy sources. By integrating these goals into the carbon market framework, India can promote a low-carbon economy that is both sustainable and inclusive (Jain, 2024) [12].

6.2 Lessons from Global Experiences
European Union Emissions Trading System (EU ETS): The EU ETS serves as a benchmark for carbon markets worldwide. Its cap-and-trade model, which sets a limit on total emissions and allows trading of allowances, has demonstrated effectiveness in reducing emissions (European Commission, 2021). India can draw lessons from the EU's experience in designing robust monitoring, reporting, and verification (MRV) systems and establishing a transparent carbon pricing mechanism (Jain, 2024) [12].

China's National ETS: China's national Emissions Trading System (ETS), launched in 2021, is the world's largest in terms of covered emitters (Liu *et al.*, 2022) [24]. China's experience underscores the importance of phased implementation and sectoral coverage in scaling up carbon markets. India can learn from China's approach to gradually expanding the scope of its carbon market and integrating various sectors over time (Jain, 2024) [12].

Korea's Institutional Design: South Korea's Emissions Trading Scheme (KETS), operational since 2015, offers insights into institutional design and stakeholder engagement. The Korean model emphasizes the role of government agencies in overseeing the market and ensuring compliance (Lee, 2015) [22]. India's CCTS can benefit from a similar institutional framework that includes clear roles and responsibilities for various stakeholders (Jain, 2024) [12].

6.3 International Coordination and Market Legitimacy
International coordination is crucial for the success of carbon markets. The European Union's Carbon Border Adjustment Mechanism (CBAM), effective from 2026, underscores the need for alignment between domestic carbon markets and international standards to avoid trade barriers and ensure competitiveness (European Commission, 2021). India's participation in global initiatives, such as climate clubs and international carbon pricing agreements, can enhance the legitimacy and effectiveness of its carbon market (Liu *et al.*, 2022) [24].

6.4 Transparency and Inclusive Design
Building domestic confidence in the carbon market requires transparency and inclusive design. Clear communication about objectives, mechanisms, and benefits fosters trust among stakeholders (Jain, 2024) [12]. Involving industry representatives, environmental organizations, and local communities in the design and implementation phases ensures that the carbon market addresses diverse stakeholder needs (Lee, 2015) [22].

6.5 Enforcement and Market Integrity
Effective enforcement mechanisms are essential to maintain market integrity. This includes stringent penalties for non-compliance and robust monitoring systems to detect and prevent fraudulent activities (Jain, 2024) [12]. Ensuring

market integrity will enhance investor confidence and encourage active participation, ultimately supporting the long-term success of the CCTS (Liu *et al.*, 2022).

7. Conclusion

Carbon markets are essential tools for mitigating climate change, creating economic incentives for reducing greenhouse gas emissions while supporting sustainable development. India's transition from the Perform, Achieve & Trade (PAT) and Renewable Energy Certificate (REC) mechanisms to the comprehensive Carbon Credit Trading Scheme (CCTS) represents a major strategic shift. While earlier mechanisms focused primarily on energy efficiency and renewable energy compliance, they were limited in ambition, scope, and market depth. The CCTS introduces an integrated framework that combines compliance and voluntary pathways, expands sectoral coverage, and establishes the institutional foundation for a credible and transparent carbon market. Although the initial emission reduction targets under the CCTS are modest, the establishment of formal governance structures—covering administration, registry operations, and oversight—creates a foundation for market credibility and investor confidence. Strengthening market infrastructure, including monitoring, reporting, and verification systems, digital registries, and streamlined project registration, will be critical for ensuring liquidity, enabling effective price discovery, and facilitating smooth operations. Equally important is fostering stakeholder trust through inclusive design, clear communication, and equitable distribution of benefits. Early experiences demonstrate that awareness, timely payments, and participatory engagement are crucial for encouraging broad participation and maintaining market legitimacy. A well-designed carbon market has the potential to generate multiple co-benefits: catalyzing emissions reductions, mobilizing climate finance, incentivizing low-carbon investments, and contributing to broader sustainable development objectives. By providing a credible platform for domestic and potential international carbon trading, India can strengthen its role in global climate action. In summary, the CCTS positions India on a promising path toward low-carbon growth. Achieving its full potential will require higher ambition, robust infrastructure, transparent governance, and strong stakeholder engagement. When effectively implemented, India's carbon market can drive sustainable development, reduce emissions, and enhance the nation's contribution to global climate goals.

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