Carbon Markets and Industrial Energy Efficiency

Assessing India's Transition from PAT to CCTS

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Abstract

This paper examines how emissions trading systems affect industrial energy efficiency incentives, drawing on India's transition from the energy efficiency-focused Perform, Achieve and Trade (PAT) scheme to the carbon-intensity-based Carbon Credit Trading Scheme (CCTS). Using a mixed-methods approach combining literature review, quantitative analysis, and expert interviews, this report provides three overarching insights. First, the impact of emissions trading systems on industrial energy efficiency is neither straightforward nor uniform, and depends on policy design, market conditions, and institutional context. Second, the Indian transition highlights both opportunities and risks: stronger market incentives may enhance energy efficiency investments under the CCTS, but more compliance options may also dilute them. Third, complementary measures are needed to fully unlock industrial energy efficiency potential, as structural barriers persist even under a well-functioning domestic carbon market. Building on these insights, five key policy recommendations to enhance industrial energy efficiency gains under the CCTS are derived: (i) ensuring market stability through consignment auctions, (ii) strengthening institutional implementation capacity, (iii) providing forward-looking guidance to industry, (iv) supporting MRV and energy management capacity building, and (v) introducing targeted financial support measures to incentivise energy efficiency investments. This study also carries broader relevance, as the EU Carbon Border Adjustment Mechanism has reignited debates on carbon market development to retain domestic revenues in many jurisdictions, including emerging economies like India. Ensuring that such systems reinforce, rather than weaken, incentives for industrial energy efficiency will be critical for cost-effective decarbonisation.

Acknowledgements: We sincerely thank Marc Ringel and Nicholas Howarth for their support and advice in the completion of this report, and Simrat Kaur for valuable comments on an earlier version. We are also grateful to Parth Kumar, Neelima Jain, and Xiaolu Zhao for their time and insightful contributions. Any remaining errors or omissions are our own.

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Glossary

BAC: Baseline-and-credit

BEE: Bureau of Energy Efficiency

CBAM: Carbon Border Adjustment Mechanism

CCC: Carbon Credit Certificate

CCTS: Carbon Credit Trading Scheme

DC: Designated Consumer

EE: Energy efficiency

EnMS: Energy Management Systems

ESCert: Energy Savings Certificate

ETS: Emissions Trading System

GHG: Greenhouse gases

ICAP: International Carbon Action Partnership

MRV: Monitoring, Reporting, and Verification

NDC: Nationally Determined Contribution

OE: Obligated Entity

PAT: Perform, Achieve, and Trade

PSAM: Price or Supply Adjustment Mechanism

SEC: Specific Energy Consumption

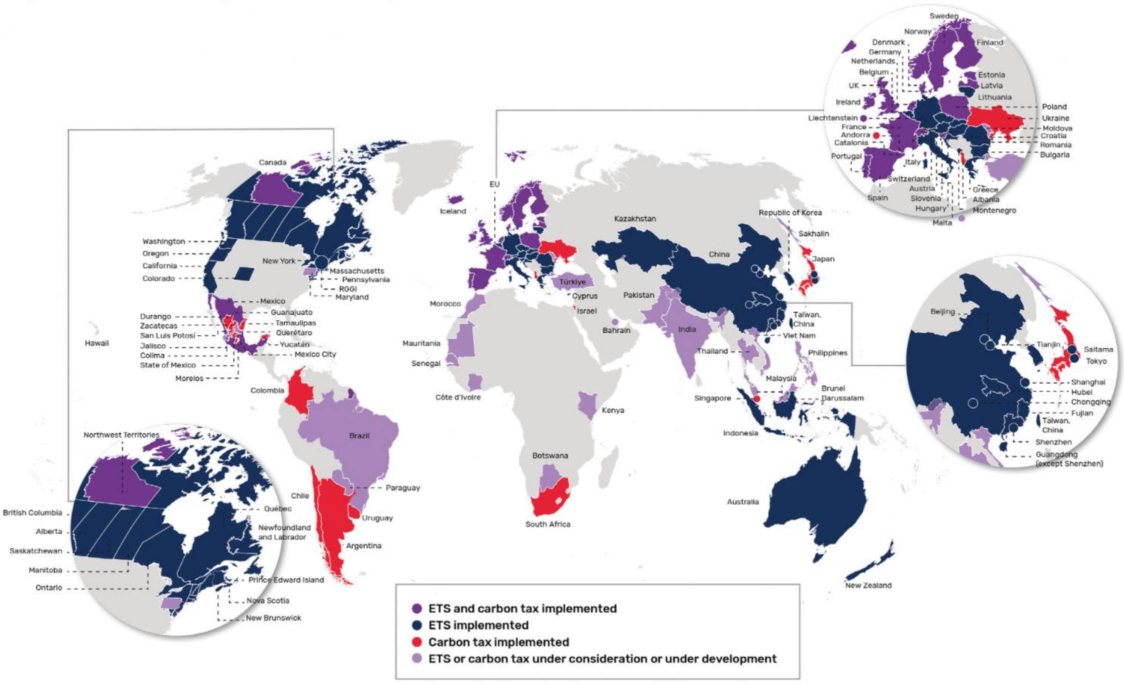
Introduction

This report investigates how the introduction of emissions trading systems (ETS) impact energy efficiency (EE) incentives in the industrial sector. Our analysis is motivated by India's recent transition from the national Perform, Achieve, and Trade (PAT) energy efficiency scheme to the Carbon Credit Trading Scheme (CCTS). This entails a move away from energy efficiency targets towards a carbon-intensity framework, which has implications on the compliance incentives firms face and as such on their energy investments and priorities. There has been limited direct investigation into the impact of carbon markets on industrial energy efficiency. This report therefore aims to address this gap by examining how industrial energy efficiency incentives evolve under emissions trading schemes, and which policy measures and design elements may be required to preserve and strengthen them in the transition from dedicated energy efficiency policies such as PAT.

Carbon pricing mechanisms have become central instruments in climate policy over recent decades. The first large-scale ETS was the European Union Emissions Trading System (EU ETS), initially launched in 2005. Under the current legislative framework, free allowances in trade-exposed ETS-covered sectors are set to be phased out gradually, accompanied by the phase-in of the Carbon Border Adjustment Mechanism (CBAM) which aims to address carbon leakage concerns, i.e. the relocation of emissions from one jurisdiction to another due to environmental policy asymmetries. Faced with an evolving landscape and incentives of CBAM, numerous countries have implemented, expanded, or announced plans to introduce domestic carbon markets (Otto, 2025), which may significantly shape incentives for industrial decarbonisation and energy efficiency investments. Figure 1 depicts an overview of the current state of carbon pricing around the world.

At the same time, energy efficiency policies remain a cornerstone of climate and energy strategies, with countries representing over 70% of global energy demand having implemented dedicated EE measures as of 2024 (IEA, 2024b). Energy efficiency policies support all aspects of the energy trilemma (security of supply, climate change, and affordability) and offer co-benefits including local employment in manually intensive retrofits, lower energy bills, and security of supply. In India alone, an estimated 50,000 jobs were created thanks to energy efficiency improvements between 2019-2024 (IEA, 2024b).

Figure 1: Global map of ETS and carbon taxes implemented, under development, or under consideration (2025)



Source: World Bank (2025)

Despite their shared objectives and importance, the relationship between carbon markets and industrial energy efficiency remains underexplored and complex. While emissions trading systems can incentivise more efficient energy use, firms may also rely on alternative compliance strategies such as fuel switching and credit purchasing, potentially weakening incentives for structural industrial efficiency improvements. This report examines how policies shape these incentives and identifies key levers to strengthen industrial energy efficiency within emerging carbon market frameworks. The methodology and outline of the paper is described in the following section.

Methodology and outline

The methodology of this paper builds on three complementary components. First, it draws on a comprehensive review of the literature surrounding industrial energy efficiency and emissions trading systems, including both international and India-specific experiences and evidence. Second, it compiles and assesses quantitative data on the PAT scheme. Third, three semi-structured interviews with industry experts were conducted between March and April 2026 to substantiate and complement our research. Annex 1 outlines the questions that guided the interviews.

The following report proceeds in four sections. The first section reviews the literature surrounding energy efficiency, ETS design, and their interaction. More specifically, the section examines the impact of ETS design on industrial efficiency outcomes, providing the foundation for a study of the effectiveness of the Indian CCTS in ensuring energy efficiency in the wake of PAT.

Section two investigates the impact of ETS schemes on industrial energy efficiency through a focus on India's transition from the PAT scheme to the CCTS. Publicly accessible data on the PAT scheme is compiled to empirically assess its effectiveness and draw relevant lessons for the design of the CCTS. The potential implications for industrial energy efficiency incentives in this transition are discussed in detail.

A third section provides policy considerations derived from a distillation of the available literature in the context of India's transition from the PAT to CCTS systems. This report proposes five main policy recommendations to maximise industrial energy efficiency. These include (i) ensuring market stability through consignment auctions, (ii) strengthening institutional implementation capacity, (iii) providing forward-looking guidance to industry, (iv) supporting MRV and energy management capacity building, and (v) introducing targeted measures to incentivise EE investments. Each of these recommendations is discussed in turn, providing a rationale for supporting their relevance to the Indian context.

The concluding section summarises the key findings presented in the paper. It also discusses potential long-term implications and possibilities for future evolution and development of the CCTS.

AI tools such as NotebookLM, ChatGPT and Claude were used to help refine language, correct spelling and grammar mistakes, and improve the overall clarity of the text. They also supported summarising and synthesising information from academic articles, along with extracting and organising quantitative data. All AI content was carefully reviewed and edited, and the original structure, ideas, sources, arguments and policy recommendations of the report are our own.

Literature review

Energy efficiency

At its simplest, energy efficiency refers to a reduction in energy use while providing a constant output (useful output / useful input). It is separate from energy savings, which refers to an absolute reduction of energy consumption.

Despite the potential embodied in energy efficiency improvements, there is a large gap between the optimal level of industrial energy efficiency and actual implementation. The observation that firms do not adopt all cost-effective energy efficiency measures is referred to as the energy efficiency gap. The IEA (2011) attributes this gap to three key barriers: economic, organisational and behavioural. Economic barriers include limited capital for upfront investments to reduce energy intensity, coupled with the uncertainty of future energy prices. Organisational barriers may emerge from the principal-agent problem, whereby different aspects of energy efficiency are delegated under distinct budgets and divisions. Such fragmentation causes asymmetric information and internal split incentives, preventing firms from making economically optimal choices (IEA, 2011). Asymmetric information can also occur externally as a market failure when information is not made accessible to companies by providers or government. Consequently, companies may over or underestimate the cost and/or energy saving potential of different solutions, leading them to pursue sub-optimal investments or opt out altogether. Lastly, even with capital, information, and coherent structures, companies might neglect energy efficiency due to behavioural factors, which could be connected to, amongst others, cultural or values-based convictions, habits, or organisational inertia (IEA, 2011).

Furthermore, measuring the degree of energy efficiency improvement in the industrial sector is complicated by the existence of simultaneous inputs and outputs occurring within a single factory, conditional on varying levels of production (Giacone & Mancò, 2012; Fais et al., 2016). The high share of small to medium-sized firms within the industrial sector further complicates energy efficiency initiatives, as they can be harder to target and face larger hurdles with regards to data collection (Worrell et al., 2008; Fais et al., 2016). Additionally, the absence of universal efficiency measurements requires more complex monitoring, verification, and reporting (MRV) systems.

Industrial energy efficiency

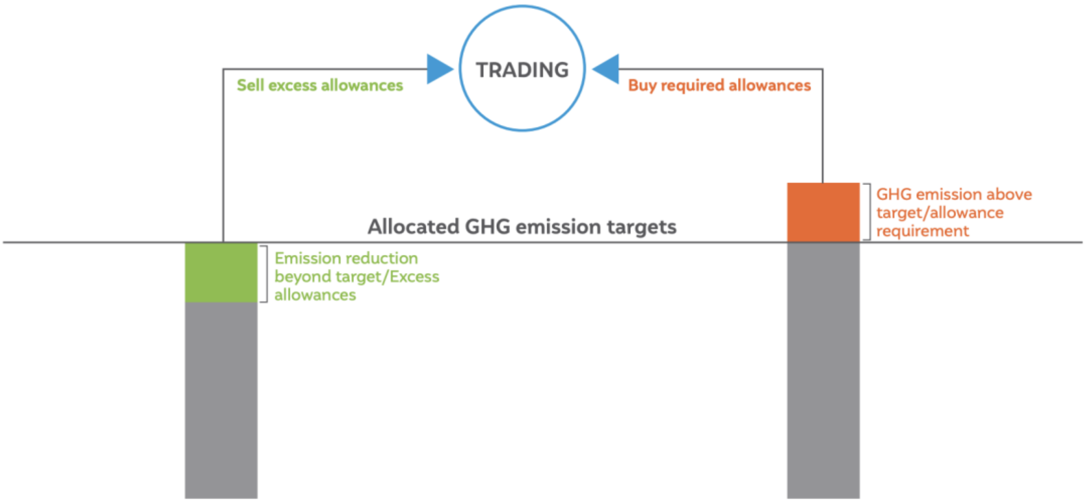
Despite challenges, the industrial sector has a particularly high potential for both energy efficiency and emissions abatement. Globally, industry accounted for around one-third of total final energy consumption in 2022 (IEA, 2023a), and roughly one-quarter of global carbon emissions (IEA, 2023c). Major areas of interest of EE measures include the emissions reductions potential (Worrell et al., 2008; IEA, 2007) and economic benefits (Worrell et al., 2003; Yahaya, 2006). The abatement costs of efficiency improvements in industry are found to be negative at -24 USD per tonne CO2 equivalent (IEA, 2020b). Similarly, increasing energy efficiency is seen as the most cost-effective means for emissions reductions within industry (Worrell et al., 2008), accounting for 20% of industry's abatement potential for 2030 (UNEP, 2024).

Emissions trading systems and energy efficiency

Despite its significant potential, the industrial energy efficiency gap persists, and policies are needed to channel investments into efficiency gains. Emissions trading systems have emerged as a preferred universalist tool for promoting abatement efforts. While the pricing of emissions under ETSs increases the costs of carbon intensive fuels and incentivises their efficient use, a policy framework focused solely on carbon reduction may not capture the full economic, energy security, and welfare benefits of EE. Indeed, the interaction between ETSs and industrial energy efficiency is complex, as efficiency gains do not always translate directly into emissions reductions, and emissions reductions do not necessarily reflect underlying efficiency improvements.

Traditional emissions trading systems are a type of market-based environmental regulation, wherein a regulator sets a holistic emissions 'cap', which is broken down into permits allocated or auctioned to covered firms. Firms must provide permits to cover their emissions or face a fine and may purchase permits from other firms with spare permits, creating a supply-demand relationship determining market price (Figure 1). Baseline-and-credit (BAC) schemes, such as the CCTS, in contrast, do not set an overall cap as they set individual emissions benchmarks for targeted firms, with permits allocated ex-post. However, they are highly similar and often treated in tandem with traditional ETS schemes due to their market-based nature and use of fungible carbon credits (ICAP, n.d.). As of 2026, 41 ETS schemes were active around the world, covering 26% of global emissions (ICAP, 2026). Prominent schemes include the EU ETS, the Chinese ETS, and the California ETS (Kukah et al., 2025). Annex 2 provides an overview of key ETS design variables and their respective impact on industrial EE outcomes.

Figure 2: Basic ETS framework



Source: Singh & Chaturvedi (2023)

India's transition towards a carbon market under the CCTS can be informed by analysing the experiences of existing ETS systems. Further investigations into the implementation, design, and impact of ETS schemes on energy efficiency in the context of China's ETS pilot programmes and Korea's ETS are presented in Annex 3 and 4. In brief, the evidence indicates that ETSs have had a positive impact on industrial EE in the Chinese context. On the other hand, the impact of the EU ETS on industrial EE is much more ambiguous. Under the EU ETS, covered emissions fell by 36% between 2013 and 2023, led by a 44% reduction in the power sector, while industrial emissions declined by 17% (Sgaravatti, 2025). Eichhammer and Chlechowitz (2021) find evidence of electricity efficiency improvements but do not attribute these to the EU ETS. Additionally, while fuel use does not decline, there is evidence of industrial fuel switching, with primary fuel switching in the power sector being the largest source of ETS-driven efficiency improvements.

It is worth noting that while EE improvements are undoubtedly desirable in isolation, they may not achieve emissions reductions in the context of an ETS. Efficiency improvements can reduce demand for permits, potentially lowering carbon prices and weakening incentives for further abatement. Similarly, the Jevons paradox suggests that increases in efficiency may lead to increases in aggregate consumption as the price of production per unit decreases, raising demand. This effect, also referred to as the rebound effect in the field of energy efficiency (Sorrell & Dimitropoulos, 2008), is observed notably by Chen et al. (2021) in China, and estimated to be 80%, i.e. four-fifths of energy savings from efficiency gains are offset by subsequent demand increases.

Overall, the literature suggests that while ETS systems can indeed incentivise energy efficiency improvements, they are insufficient at achieving optimal efficiency outcomes in isolation (IEA, 2011), and should therefore be paired with or supported by additional policy measures directly focused on energy efficiency (Grubb et al., 2023).

The role of Energy Management Systems

Energy Management Systems (EnMS), broadly defined as the standardised frameworks and processes responsible for corporations' energy use and management, are both key to achieving industrial efficiency goals and highly impacted by ETS schemes. Such systems allow firms to consistently achieve efficiency improvements and cost-savings, playing a crucial role in data collection and implementation of internal efficiency initiatives. The predominance of EnMS is highlighted through the popularity of the International Standards Organisation's ISO 50001 rating, which provides a framework for successful EnMS development. In 2023, 58% of the ISO certificates awarded to industry were provided on the grounds of efficiency improvements (IEA, 2024a).

The primary motivator behind firms' decisions to implement and develop functional EnMS is increasing energy costs (Javied et al., 2015), which can be amplified in the form of a carbon price through the ETS. Internal carbon pricing, or "shadow" pricing, is highly relevant in this respect. Shadow pricing refers to the incorporation of wider carbon prices (e.g. established by an ETS) into corporate energy decision-making and financial strategic planning. This essentially constitutes an additional lever for EnMS operators to optimise energy use. In other words, the financial impositions associated with ETS schemes not only increase the value of EnMS as a means of responding promptly and appropriately to market signals, but also present new opportunities for EnMS to increase efficiency and decrease emissions through financially feasible means.

EnMS and energy auditing also play a crucial role in enabling firms to comply with MRV obligations under ETS schemes. The heterogeneity of firms within industrial sectors in terms of size, existing data infrastructure, and administrative capacities pose significant challenges with regards to MRV design. Uniform monitoring and reporting requirements may be inappropriate and can impose disproportionate burdens on smaller firms. Tools such as sector wide standardised monitoring plans or tiered approaches to data collection (wherein larger companies with higher monitoring capacities are required to submit more detailed/extensive data) can serve as solutions to this issue (Tang et al. 2018).

Case study: India's transition from PAT to CCTS

India represents a particularly relevant case study for analysing the interaction between compliance carbon markets and industrial energy efficiency incentives. As one of the world's largest and fastest-growing economies, India plays an important role in global emissions trajectories, with its industrial sector accounting for around a quarter of the country's total emissions (IEA 2023b). India's in March 2026 updated nationally determined contribution (NDC) commits to reducing the emissions intensity of GDP by 47% by 2035 compared to 2005 and reach net-zero emissions by 2070 (PIB India, 2026). The transition from the energy efficiency-focused PAT scheme to the carbon-intensity based CCTS therefore represents a critical policy shift. This case study also carries broader relevance, as CBAM has reignited debates on carbon market development to retain domestic revenues in many jurisdictions (see Otto, 2025). The case study thus offers insights that can inform similar policy transitions, particularly in other emerging economies.

Perform, Achieve and Trade (PAT)

Introduced in 2012 under the National Mission for Enhanced Energy Efficiency (BEE, 2023), the Perform, Achieve and Trade (PAT) system constituted India's first major market-based mechanism for industrial regulation, emerging in response to the country's rapid economic expansion and the resulting surge in industrial energy consumption. The operation of PAT is grounded in the technical concept of Specific Energy Consumption (SEC), which measures the amount of energy required per unit of physical industrial output (BEE, 2025a).

The scheme is governed by the Bureau of Energy Efficiency (BEE), operating under the authority of the Ministry of Power (Kumar & Agrawal, 2024), which identifies entities classified as Designated Consumers (DCs) across 13 highly energy-intensive sectors. These entities, including thermal power, iron, steel and cement plants, are covered if their annual consumption exceeds a predefined threshold, such as 30,000 tonnes of oil equivalent (toe) for the cement sector or 3,000 toe for the textile sector (BEE, 2023).

The system operates through three-year performance cycles, at the beginning of which the government notifies each entity of a personalized target for reducing its SEC. Targets are determined based on each plant's level of energy consumption and relative efficiency, allowing more ambitious requirements to be imposed on the least efficient plants while rewarding the efforts of technological leaders (BEE, 2023). It is important to note that the PAT system evolved toward a rolling cycle model starting in 2017 (BEE & Vasudha Foundation India, 2024). This means that new cycles are notified annually to include additional sectors or new entities, creating a schedule in which several three-year cycles may overlap over time across the national industrial sector (Kumar & Agrawal, 2024).

At the end of each three-year cycle, monitoring and verification is carried out by empanelled accredited energy auditors (BEE, 2023), including both independent experts and auditing firms accredited by the BEE. Entities that succeed in reducing their energy intensity beyond their assigned target receive Energy Saving Certificates (ESCerts), corresponding to one toe. Conversely, companies who fail to meet their target must compensate by purchasing certificates on market platforms such as the Indian Energy Exchange or Power Exchange India Limited (BEE, 2023). This mechanism creates a direct financial incentive in which efficiency becomes a monetizable asset (BEE, 2023), while inefficiency translates into an operational cost.

Carbon Credit Trading Scheme (CCTS)

The introduction of the Indian Carbon Market in 2023 through the Carbon Credit Trading Scheme (CCTS) marks a fundamental shift in the country's industrial climate strategy. This new system moves from an energy efficiency metric to a greenhouse gas (GHG) emission intensity metric, defined in terms of tonnes of CO_2 equivalent (tCO_2e) emitted per unit of production (BEE, 2024a). The CCTS is based on a baseline-and-credit model built on relative performance. Unlike PAT, the CCTS directly accounts for process-related direct emissions (Scope 1) as well as indirect emissions linked to electricity and heat consumption (Scope 2). Additionally, some Scope 3 emissions, including the import and export of intermediary products, will be considered through a system of notional emissions (calculated based on standardised benchmarks rather than directly measured) to ensure consistency across entities (ICAP, 2025).

Under this system, the government sets annual emission intensity reduction targets for obligated entities according to sectoral trajectories extending to 2030 (BEE, 2024a). Similarly to the logic of the PAT scheme (see Figure 3), a company that achieves an emission intensity below its target is rewarded with

Carbon Credit Certificates (CCCs), each corresponding to one tonne of CO_2 equivalent, calculated based on the difference between the target and achieved emission intensity multiplied by output. The system is designed to be flexible. Entities may use banking to save CCC credits for future years when targets become more stringent (Kumar & Agrawal, 2024). If a company exceeds its intensity target, it must purchase CCCs on the market to offset its excess emissions. The market infrastructure builds on existing power exchanges (BEE, 2023). Oversight is ensured by the Central Electricity Regulatory Commission, which defines trading rules and safeguards market transparency and integrity (BEE, 2024a).

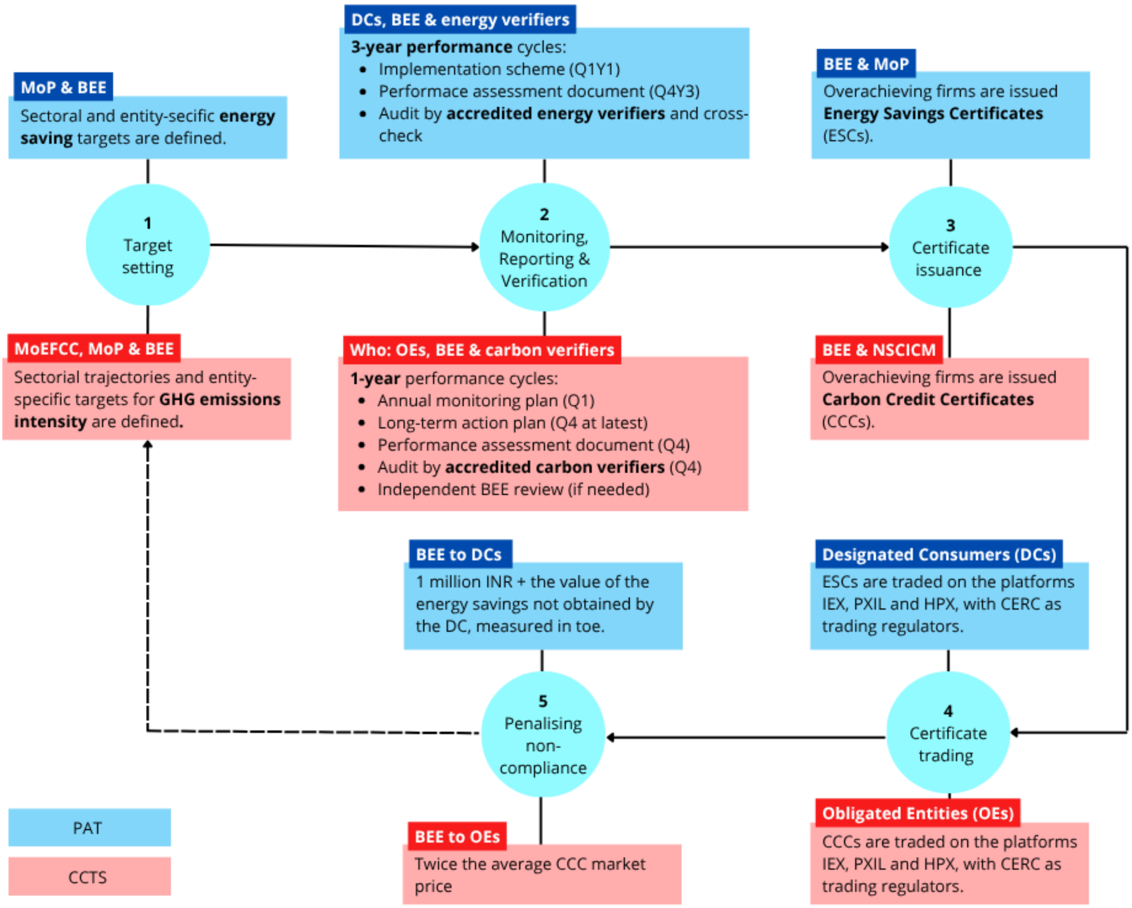
The initial scope of this compliance mechanism targets nine major industrial sectors with significant Scope 1 and Scope 2 emissions. These sectors include petrochemicals, iron and steel, cement, aluminium, fertilizers, pulp and paper, chlor-alkali, textiles, and petroleum refineries (ICAP, 2025). For each obligated entity, the Ministry of Environment, Forest and Climate Change notifies annual GHG emission intensity targets in alignment with India's NDC (BEE, 2024a).

The compliance protocol imposes strict monitoring and reporting obligations on obligated entities similar to the PAT. Each company must submit a detailed monitoring plan to the Bureau of Energy Efficiency within three months of the start of the compliance period (BEE, 2024a), supported by the Indian Carbon Market Portal, a centralised digital platform enabling MRV processes. At the end of the compliance year, entities have four months to submit their GHG emissions report and performance assessment document, prepared using standardised reporting formats and official pro formas defined by the BEE and verified by an accredited carbon verification agency (BEE, 2024a). Accreditations are granted by the BEE, building on the existing pool of energy auditors developed under the PAT scheme (Kumar & Agrawal, 2024). The performance assessment concludes with a verification opinion issued at a reasonable level of assurance, confirming that the reported data are free from material misstatements, omissions, or errors, based on a defined materiality threshold (e.g. 2% of total reported emissions) (BEE, 2024a).

The CCTS also introduces an Offset Mechanism allowing non-obligated sectors, such as agriculture, forestry, or waste management to generate CCCs by implementing certified carbon reduction or removal projects (BEE, 2024a). The Offset Mechanism therefore creates an additional source of credits originating outside the industrial sector.

A more detailed and structured comparison between the two systems can be found in Annex 5.

Figure 3: Comparison of PAT and CCTS compliance cycles



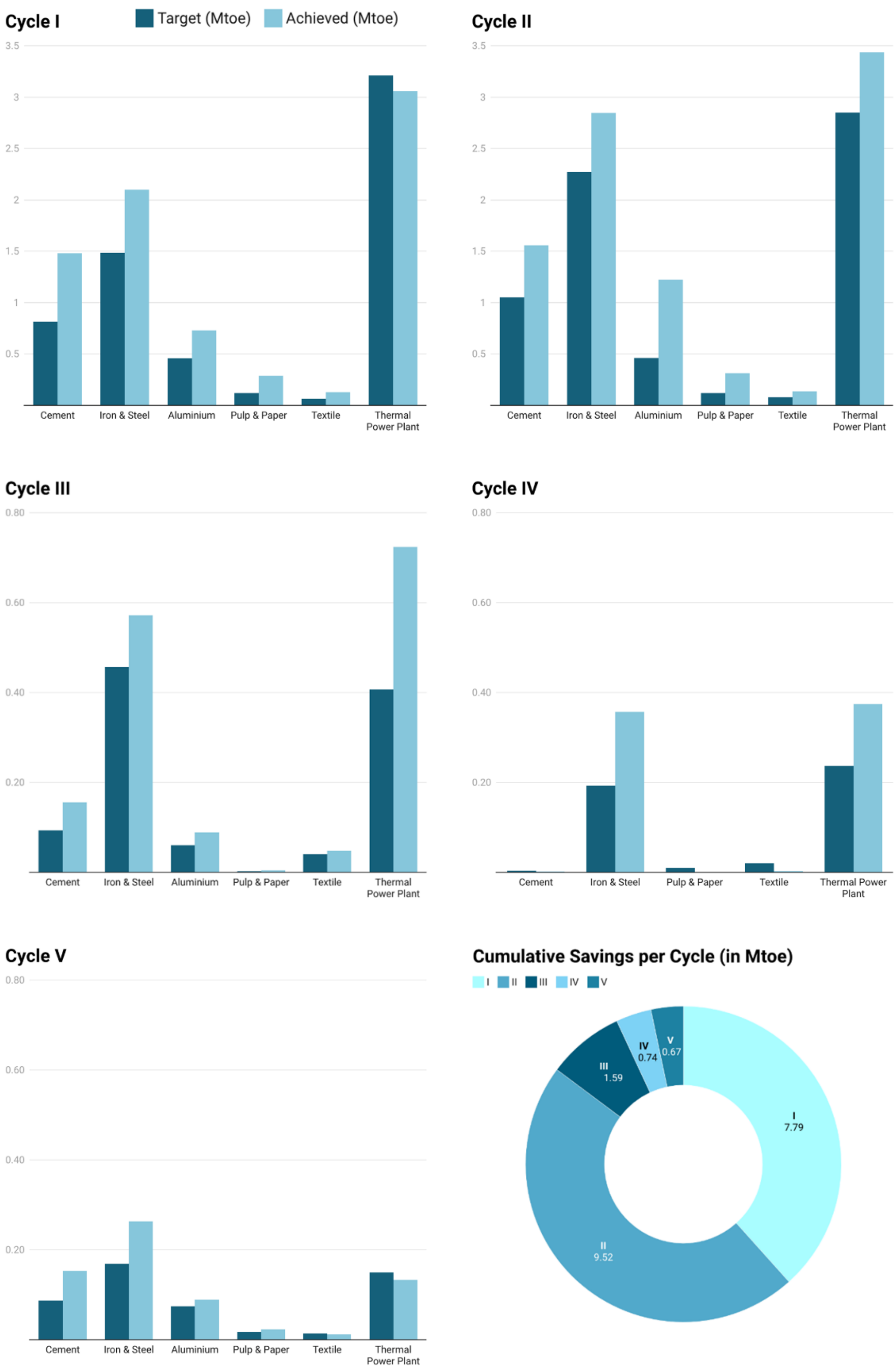
(Authors' own illustration) Data source: BEE (2024a)

Empirical assessment and key lessons of PAT

In the following section, the PAT scheme is assessed through two different avenues: (i) data from the impact assessment conducted by the BEE (2023), and (ii) the broader academic literature. Evaluating the effectiveness of PAT is particularly relevant as the scheme is the predecessor of the CCTS and shares common design principles, including intensity-based targets, a baseline-and-credit structure, and ex-post issuance and trading of credits.

The impact assessment by the BEE (2023) presents the most comprehensive overview of the scheme's performance, covering all cycles and industrial sectors until 2022. Over the five analysed cycles and across all sectors, the PAT scheme achieved total energy savings of 25.77 Mtoe. Although the PAT

Figure 4: Comparison of achieved energy savings and notified



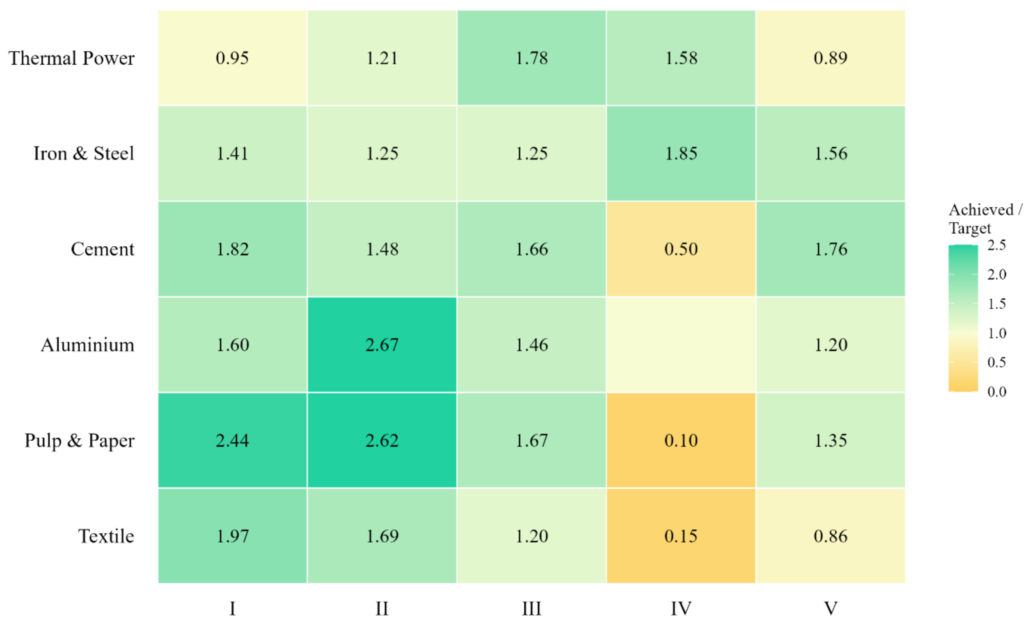
Notes: Energy savings and targets are expressed in million tonnes of oil equivalent (Mtoe) and represent avoided energy consumption relative to baseline specific energy consumption. Values are aggregated at the sectoral level and may mask heterogeneity across individual DCs. Authors' own illustration. Data source: BEE (2023) scheme is based on energy intensity metrics, the BEE (2023) reports absolute energy savings. These are calculated by multiplying the change in energy intensity with actual production levels:

$$Energy\ savings\ =\ (achieved\ SEC\ -baseline\ SEC)\ \times\ actual\ production$$

Consequently, reported savings reflect avoided energy use, and not necessarily an absolute reduction in total energy consumption. Comparisons across PAT cycles should be undertaken with caution as the number of DCs varied across cycles (see Annex 6). Moreover, energy saving target levels have been higher in cycle I and II than in later cycles, potentially reflecting the adoption of low-cost efficiency improvements in the early stages of the scheme. Figure 4 illustrates energy savings and targets across PAT cycles for the main industrial sectors.

The data shows consistently high levels of target achievement. As depicted in Figure 5, the pattern of overachievement is particularly pertinent for Cycles I to III, whereas Cycles IV and V exhibit lower achievement ratios. While the BEE data shows that there were significant energy intensity reductions across these industries throughout the PAT lifecycle, this does not necessarily mean that it was the PAT scheme that delivered additional energy efficiency gains. In fact, reductions could also be the results of factors such as changes in fuel and electricity prices, (autonomous) technological improvements, and other policy interventions.

Figure 5: PAT achievement ratios across PAT cycles in main industrial sectors



Notes: The achievement ratio is defined as achieved energy savings divided by notified targets. A value of 1 indicates exact compliance, while values above (below) 1 indicate overachievement (underachievement). Values are displayed at the sector level and may mask variation across individual DCs. Authors' own illustration based on data from the BEE (2023).

Annex 7 presents a summary table of the empirical literature on PAT, identified through a combination of keyword-based and targeted literature exploration. Early contributions emphasise design challenges, particularly in the context of target setting. Bhandari and Shrimali (2018) find that PAT benchmarks in cycle I were insufficiently ambitious to drive additional efficiency reductions. Sahoo et al. (2017), using data envelope analysis models, find that PAT targets for the thermal power sector in cycle I were markedly lower than their actual potential.

More recent firm-level econometric studies estimating the causal effects of the PAT scheme find mixed results. Some show modest improvements in energy efficiency, such as reductions of 2.7% in cement and 1.6% in fertiliser (Oak & Bansal, 2022), or modest reductions in iron and steel and textiles (Chauhan & Thangavel, 2025a, 2025b). Others, however, find no statistically significant impact. Misra (2019) reports no measurable effect in cement and iron and steel, while Pal et al. (2024) also find no effects, using a data sample of six PAT-governed industries.

The limited effect of PAT to incentivise additional energy efficiency investments is explained by significant credit surpluses due to persistent target overachievements. This tendency to initially set generous targets to ease market transition is a common pattern across many experiences with ETSs. Based on the empirical evidence and expert interviews, PAT was no exception. Technological and structural factors were likely the most important drivers of the efficiency gains in PAT industries. However, the experience from the PAT scheme provides a decade of experience on how a baseline-and-credit system operates in India. Several important lessons can be drawn for the transition to CCTS.

First, PAT established the institutional and technical foundations for an Indian carbon market infrastructure. According to IETA (2023), roughly 45,000 professionals were trained through capacity-building programs associated with PAT. This includes an ecosystem of accredited energy auditors, energy managers, and verification bodies. By operationalising an intensity-based trading system, PAT thus strengthened capacities within firms and public authorities to achieve industrial energy efficiency outcomes. It also lowers implementation barriers for the CCTS, e.g. in developing MRV systems.

Second, PAT showcased the importance of benchmark stringency for sustained incentives and trading volumes. According to Shrivastava et al., 2024, the “Performance” and “Achieve” components of the PAT scheme functioned (also see Figure 4), while the “Trade” element was undermined by low certificate demand due to the high overachievement rates. As a result, the BEE had to extend the trading window multiple times for different compliance cycles. Furthermore, the BEE has only issued certificates for its first three cycles, indicating that the market oversupply is likely to be exacerbated without regulatory modifications (Kumar & Agrawal, 2024). That this delay in certificate issuance erodes confidence in the market mechanism was confirmed by the expert interviews.

Third, PAT had relatively weak enforcement mechanisms and penalties. Paying the penalty was sometimes cheaper than engaging in the market (Shrivastava et al., 2024), and enforcement has been lenient in practice. After repeated extensions of the trading window in cycle II, non-compliant DCs were not penalised by the BEE (Kumar & Agrawal, 2024). One interviewee attributed this leniency to the fact that pursuing legal enforcement is often more costly than the expected penalty revenue.

Overall, as one interviewee summarised, the PAT scheme "worked too well on paper, but not so much in practice," reflecting the gap between its conceptual design and ambition, and providing sizable monetary incentives for additional industrial efficiency improvements.

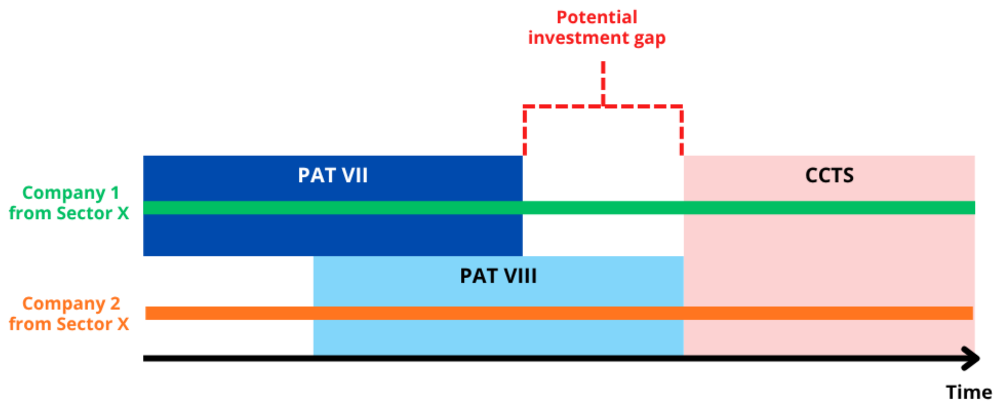
Energy efficiency implications of a gradual transition to the CCTS

The transition from PAT to CCTS is set to take a sequential approach from 2025 onwards (ICAP, n.d.). As industrial entities complete their respective three-year performance cycles under PAT, they will receive new reduction targets under CCTS. As such, OEs will gradually transfer from PAT to the new carbon market.

a. <u>PAT as a potential roadblock for CCTS</u>

In terms of preserving EE incentives, some analysts have questioned whether running PAT in parallel with CCTS might impede the latter from reaching its full potential (Kumar & Agrawal, 2024). Entities from the same sector currently find themselves in different PAT cycles, and may therefore be subjected to CCTS obligations at different times, creating unfair competition in the market. However, according to one interviewee, the Indian government has signalled that entire sectors will be transitioned into CCTS simultaneously to avoid this problem. Nonetheless, it remains unclear what requirements entities wrapping up their current PAT cycles will be subjected to while waiting for those in later cycles. Such ambiguity risks delaying efficiency investments while industries wait for clear signals (see Figure 6). Nevertheless, as highlighted by another interviewee, establishing a new carbon market is a comprehensive process and both governments and industries need time to adjust, especially in an emerging economy like India. Thus, certain trade-offs may be necessary to smooth implementation in the short-term.

Figure 6: Potential EE investment gap in transition from PAT to CCTS



(Authors' own illustration)

Another important concern during the transition period is that of MRV capacity, both from public institutions and the private sector. Figure 3 illustrates how PAT and CCTS will be largely managed by the same public bodies, with the BEE given major responsibilities as regulator for both systems. Still, delays in issuing certificates and the lack of enforcement under PAT indicate that the capacities of the Bureau might be limited. CCTS constitutes a much more complex system than PAT, requiring digitalised infrastructure and more advanced training of auditors to ensure accurate and transparent data collection and MRV (Kumar & Agrawal, 2024). Moreover, the shortening of the compliance cycle from three years under PAT to one year under CCTS entails a heavier documentation load, both on industries and the BEE. Given that the BEE has already been delayed in notifying entities of their first CCTS targets, leading to pro-rata adjustments, questions may be raised about the current institutional capacity to ensure the credibility and reliability of the system (Singh & Sharma, 2026). If the BEE falls short in maintaining its responsibilities for target-setting, MRV, and compliance, this might quickly weaken industries' confidence in the system, and subsequently their incentives to invest in carbon abatement measures, including energy efficiency.

b. The risk of shifting compliance pathways away from energy efficiency improvements

When transitioning from PAT to CCTS, industrial regulation will effectively shift from one avenue of compliance (i.e. energy efficiency measures) to multiple possible compliance avenues, including fuel switching and carbon capture and storage. EE measures often remain the low hanging fruit, providing industries with negative to low-abatement cost options. This is clearly the case for key CCTS-covered sectors like aluminium and cement, demonstrated in the marginal abatement cost curves produced by the Council on Energy, Environment and Water displayed in Figure 7 and 8 (Sripathy et al., 2024;

Nitturu et al., 2023). In fact, under the current targets, both industries meet compliance requirements through energy efficiency measures alone (Singh & Sharma, 2026). It is therefore economically rational to assume that industries would exhaust energy efficiency options before addressing more expensive compliance measures under CCTS.

Figure 7: Marginal abatement cost curves for India's aluminium industry

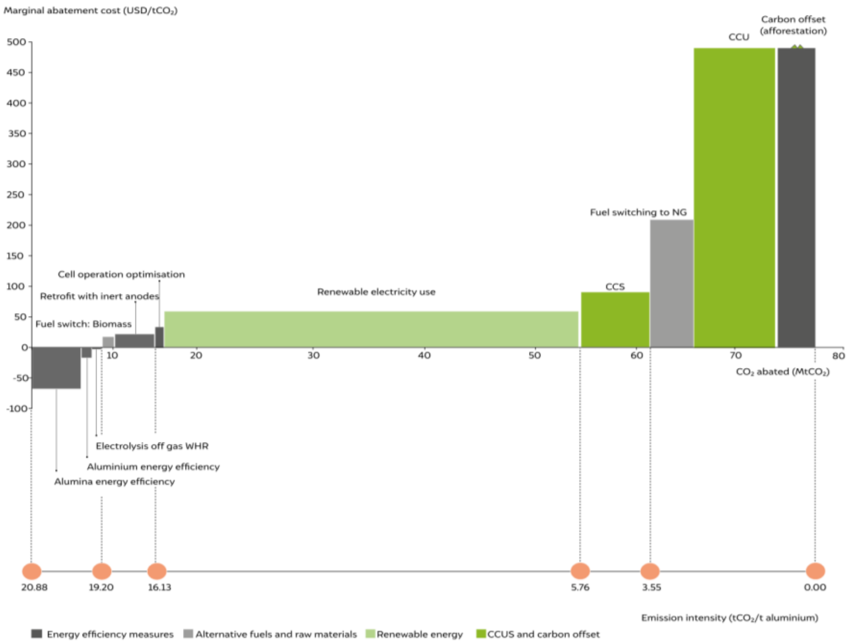
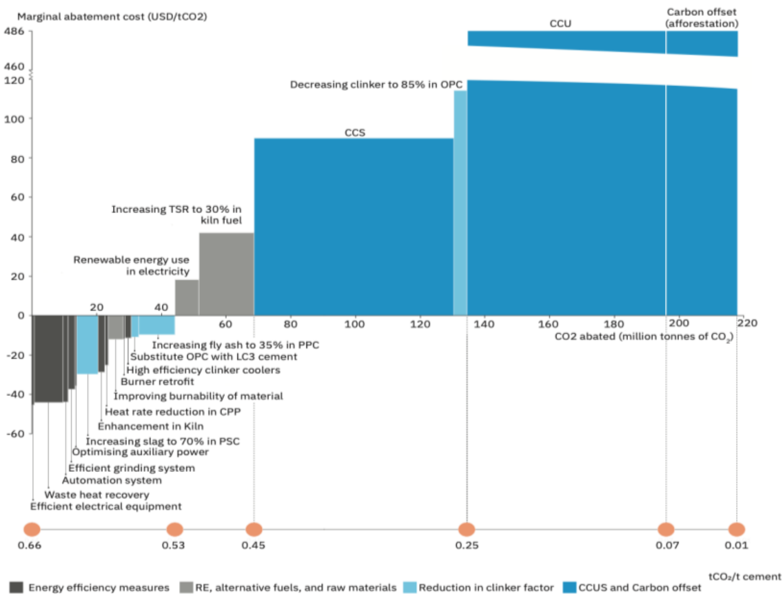


Figure 8: Marginal abatement cost curves for India's cement industry



Source: Singh & Sharma, 2026

Nevertheless, international experience on the interlinkages between carbon markets and energy efficiency indicates that this is not always the case in practice. According to a recent survey conducted by ABB (2026), senior industrial leaders in India have identified three key barriers to energy efficiency: (1) resistance from the workforce to new technology (41% of respondents), (2) specialist resource shortages (42%), and (3) lack of digital skills (42%). These findings indicate that Indian firms might be facing behavioural and organisational challenges related to internal capacity and work culture, which are limiting their propensity to pursue energy efficiency measures regardless of economic rationality. As such, the CCTS as a stand-alone policy appears insufficient to incentivise energy efficiency investments. Supplementary measures may therefore be required to address these barriers.

Additionally, as echoed in the interviews, marginal abatement cost curves often portray energy efficiency as a one-time measure to be crossed off a list. However, to maximise its potential under CCTS, stakeholders should take a "layered approach" to energy efficiency, recognising that technological progress will open new doors further down the line to optimise energy consumption and subsequently reduce GHG emissions. While other decarbonisation methods, such as fuel-switching, will be necessary to meet stricter CCTS targets in the future, industries should therefore be incentivised to continuously explore energy efficiency opportunities as they progress.

Policy recommendations

1. Ensure stable market conditions through consignment auctions

Managing potential supply-demand imbalances is key to maintaining credible long-term investment signals for industrial efficiency improvements under the CCTS scheme. Global carbon market experiences and learnings from PAT show that price or supply adjustment mechanisms (PSAMs) can stabilise the market and prevent both persistent oversupply and excessive price volatility.

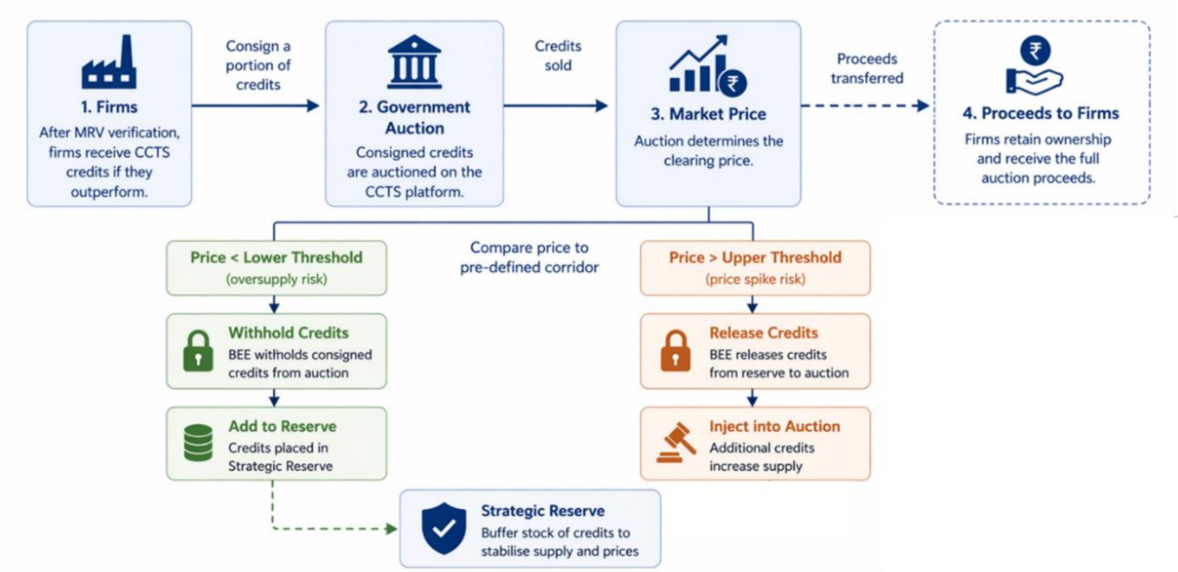
While there are many possibilities of enacting PSAMs in practice, establishing a consignment mechanism for India's evolving CCTS framework represents a particularly suitable policy consideration to ensure that certificate prices remain credible and predictable. Without such stability, firms may prioritise short-term compliance strategies over structural energy efficiency improvements, with long payback periods and high upfront capital requirements.

Establishing a consignment mechanism provides the foundation for regulators to stabilise market supply. Unlike regular cap-and-trade systems, credits under the CCTS are only issued after firms' performance is verified. This gives the BEE no dedicated handling of intervening in the market, e.g. in times of external shocks, without making ad-hoc rule changes that undermine market confidence - as seen with issuance delays under the PAT scheme. A consignment mechanism offers a pragmatic solution that can build the necessary infrastructure for PSAMs to function.

In practice, this could take the following form: firms must consign a portion of their credits after each compliance cycle to a government-run auction. They maintain the property rights of the credits and receive the full proceeds of the auction. If prices fall below a predetermined threshold, e.g. due to an oversupply of certificates in the market, the BEE can withhold consigned credits from the auction temporarily and put them into a dedicated reserve to stabilise the market. Conversely, if prices increase, additional credits from the reserve could be released through the auction, as illustrated in Figure 9.

Over time, this could increase price stability and market confidence, much like the EU Market Stability Reserve or other successful PSAMs did. Shrivastava et al. (2024) analyse and describe in greater detail how such a mechanism could be implemented under the CCTS. The authors also suggest a vintage-based credit classification system as a complementary PSAM to potentially regulate excessive banking. This could also help level the playing field by preventing firms with large legacy credit surpluses from gaining a structural cost advantage over newer or smaller participants.

Figure 9: Consignment auction mechanism as a foundation for market stability



(Authors' own illustration)

2. Strengthen institutional capacity and market integrity for robust implementation

Experience from PAT shows that delayed implementation and weak enforcement can undermine market integrity and investment incentives for EE improvements. Measures should therefore be taken to build the necessary governmental capacity to maintain credible MRV and enforcement responsibilities, such as timely target notification and systematically issuing penalties for non-compliance. Specifically, a coordination mechanism between public bodies playing a role in the carbon market should be established to reduce administrative inefficiencies and eliminate duplicated functions throughout MRV processes, freeing up institutional capacity to ensure coherent implementation and credible enforcement (also see Ray & Bandyopadhyay, 2026). Furthermore, the CCTS framework should ensure that penalties are financially dissuasive. Under the current design, non-compliance is penalised at twice the prevailing certificate price. While this is likely to create a stronger deterrent than under PAT, market integrity ultimately depends on the level and stability of credit prices and on systematic enforcement.

3. Provide forward-looking guidance

For industries to commit capital to energy efficiency improvements, they need to be sufficiently informed about their obligations and compliance options, especially when adjusting to the new CCTS system. To avoid delayed investments in energy efficiency, the Indian government should consider launching a public information campaign towards sectors set to transition from PAT to CCTS, addressing the current ambiguity as to how this will be carried out in practice. The Indian Carbon Market Portal, launched in March 2026, could serve as a key channel in this regard. Other possible measures include sector-specific CCTS handbooks, webinars, or a compliance helpdesk to further support industries in this transition.

4. Combine industrial MRV capacity-building with energy management upskilling

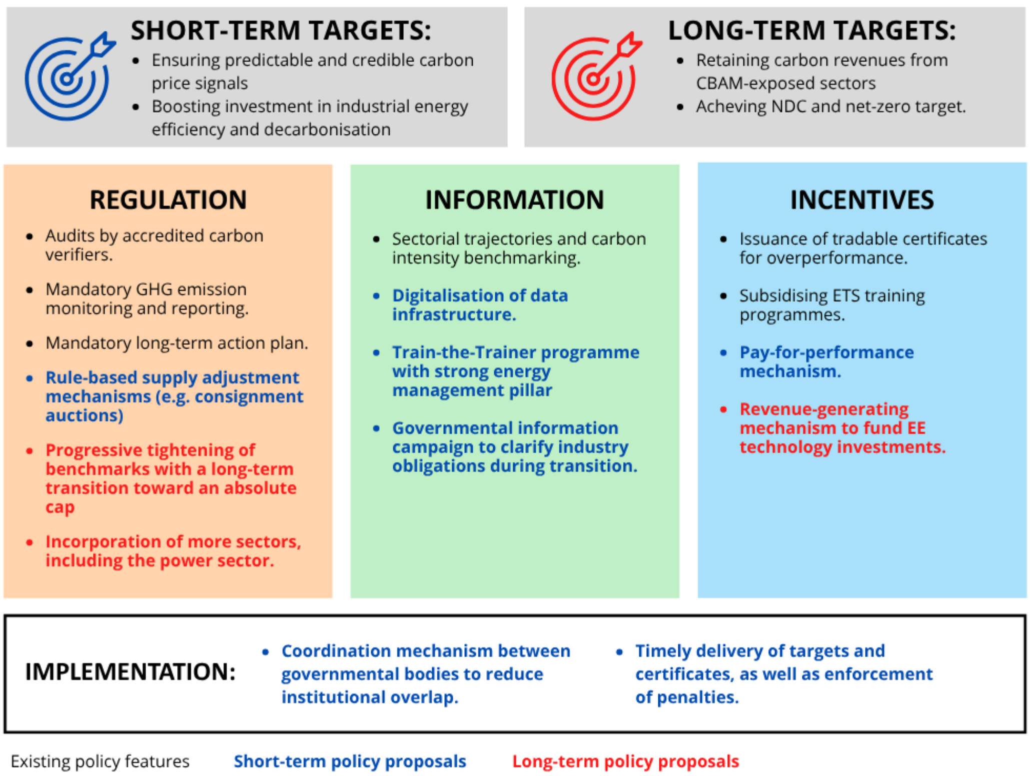
The CCTS will require industries to manage more advanced MRV systems than under PAT, including GHG accounting and verification. To be able to catalyse larger-scale upskilling, inspiration should be taken from the Train-the-Trainer Programme carried out under the EU-China Dialogue and Cooperation on ETS-related Policies and Measures' Project. The programme is composed of online general training, virtual self-study, and physical intensive training, with the overarching aim of increasing the number of certified ETS trainers in China (EU Delegation to China, 2025). Given the limited governmental means to provide training to industries directly, this targets resources directly towards increasing external training capacity, with the potential of both accelerating upskilling and creating jobs. By integrating a strong energy management pillar, it could also serve as a key strategy to address energy efficiency barriers – such as lack of expertise or resistant work culture – enhancing both the skillsets and mindsets for frequently re-visiting energy efficiency compliance avenues.

5. Implement targeted financial support measures

International experience shows that the lack of upfront capital is a key barrier to energy efficiency investments. The Indian government should therefore consider introducing targeted financial support, such as concessional credit lines and public guarantee schemes, to further incentivise firms to pursue energy efficiency compliance options. These could be complemented by pay-for-performance schemes for firms that significantly outperform their carbon intensity targets. Financing could come from public development banks, a small levy on carbon credit trades, and international climate finance. India's Partial Risk Sharing Facility for Energy Efficiency offers a relevant precedent (World Bank, 2015).

Figure 10 provides an overview of the described policy considerations, structured along the IEA Energy Efficiency Toolkit (2025): regulation, information and incentives. It also highlights existing policy features and potential long-term considerations related to carbon market development and the strengthening of industrial energy efficiency in India.

Figure 10: Overview on measures for incentivising energy efficiency under CCTS



(Authors' own illustration)

Conclusion

Using a mixed-methods approach, this paper set out to examine the relationship between compliance carbon markets and industrial energy efficiency, with a focus on India's current transition from the Perform, Achieve and Trade (PAT) scheme to the Carbon Credit Trading Scheme (CCTS). The analysis provides three overarching insights.

First, while emissions trading systems can address market failures and barriers to industrial efficiency investments, their direct impact on more efficient industrial energy use is neither straightforward nor uniform. Investigations into the Chinese, EU, and Korean emissions trading systems show that the relationship depends critically on policy design, market conditions, and the broader institutional context.

Second, the Indian case study illustrates both the opportunities and risks associated with transitioning from a dedicated energy efficiency policy framework to a domestic carbon market. On the one hand, CCTS could strengthen additional energy efficiency investments by ensuring more credible and predictable incentives than under PAT. At the same time, the shift from a single compliance pathway under PAT to multiple compliance avenues under CCTS - such as fuel switching or carbon capture - risks weakening the focus on industrial energy efficiency improvements.

Hence, our third key finding is that ETS schemes alone are insufficient to fully unlock industrial energy efficiency improvements, despite the fact that they typically remain the "low-hanging fruit" in terms of abatement cost options.

Based on the case study analysis, five policy recommendations to enhance industrial energy efficiency under the CCTS are put forward: (i) ensuring market stability through consignment auctions, (ii) strengthening institutional implementation capacity, (iii) providing forward-looking guidance to industry, (iv) supporting MRV and energy management capacity building, and (v) introducing targeted financial support measures to incentivise energy efficiency investments.

The relevance of this investigation extends beyond the Indian context, particularly in light of the global uptake of carbon pricing schemes following the EU's introduction of CBAM. India is one of several emerging countries developing domestic carbon markets in response to shifting international trade and climate policy landscapes. Therefore, the findings of this report offer broader insights into the challenges, trade-offs and opportunities associated with aligning carbon market design with industrial efficiency objectives in developing economies.

One key limitation of this report is that - at the time of writing - the CCTS is not yet fully operational. Once data on the CCTS becomes available, future research should examine its effects on energy efficiency, particularly as installations are expected to move from PAT to the new scheme.

Lastly, a central challenge for emerging carbon markets lies in managing the balance between flexibility and credibility. While gradual implementation and policy flexibility may be necessary at first, a longer-term vision is needed to effectively retain carbon revenues domestically rather than allowing them to flow to importing jurisdictions with a CBAM in place, like the EU. To achieve this objective, strengthening the domestic carbon market, for instance through revenue-generation mechanisms and allocation frameworks that channel resources into energy efficiency investments, should be a priority in the evolution of the CCTS. This could also promote economic, security and social co-benefits of industrial energy efficiency gains, such as reduced energy import dependence. Ultimately, as systems become more widespread, ensuring that compliance carbon markets effectively support industrial energy efficiency will be critical for achieving cost-effective and socially beneficial decarbonisation.

Bibliography

ABB. (2026). End-to-End Energy Intelligence: Closing the Efficiency Execution Gap. Retrieved from https://library.e.abb.com/public/01f98d8441d048ea92fbac2273641769/4MWA000347_en_End-to-end_energy%20_intelligence_Closing_the_efficiency_execution_gap_report_RevA.pdf?x-sign=s%2fLmYgxaRNc7Ee%2brREDjeQp%2bOB1VwO4vUH8vzj5tsOwtAhxqSc7whPzyYkSTLkev

Bhandari, D., & Shrimali, G. (2018). The perform, achieve and trade scheme in India: An effectiveness analysis. *Renewable and Sustainable Energy Reviews,* 81, 1286-1295.

Bureau of Energy Efficiency. (2023). Impact of energy efficiency measures for the year 2022-23. Government of India. Retrieved from https://beeindia.gov.in/sites/default/files/publications/files/Impact Assessment 2022-23_ FINAL Report.pdf

Bureau of Energy Efficiency. (2024a). Detailed Procedure for Compliance Mechanism under CCTS. Retrieved from https://beeindia.gov.in/sites/default/files/Detailed%20Procedure%20for%20Compliance%20Procedure%20under%20CCTS.pdf

Bureau of Energy Efficiency. (2024b). Office memorandum: Approved Sectors in Offset Mechanism under CCTS by Central Government.

Bureau of Energy Efficiency. (2025a). Perform Achieve Trade (PAT). Retrieved from https://www.beeindia.gov.in/perform-achieve-and-trade-pat

Bureau of Energy Efficiency. (2025b). Detailed Procedure for Offset Mechanism under CCTS.

Bureau of Energy Efficiency & Vasudha Foundation India. (2024). India Energy Scenario for the year 2023-24 Retrieved from https://beeindia.gov.in/sites/default/files/BEE_India_Energy_Scenario_Report-2024_web_version-rev2.pdf

Bureau Veritas. (2025, August). BEE announcement: ISO 14064 series carbon footprint lead verifier training. Retrieved from https://www.bureauveritas.co.in/bee-announcementiso-14064-series-carbon-footprint-lead-verifier-training

Chauhan, A., & Mohanasundari, T. (2025). The impact of the Perform, Achieve, and Trade (PAT) scheme on energy intensity: Evidence from the pulp and paper industry. *Energy Sources, Part B: Economics, Planning, and Policy*, 20(1), 2588253.

Chauhan, A., & Thangavel, M. (2025a). Assessing the impact of the Perform, Achieve, and Trade scheme on energy efficiency in India's iron and steel sector. *Energy Policy*, 198, 114480.

Chauhan, A., & Thangavel, M. (2025b). The effect of perform, achieve, and trade scheme on India’s textile sector: A panel analysis. *Economic Affairs*, 70(1), 15-21.

Chen, Z., Song, P., & Wang, B. (2021). Carbon emissions trading scheme, energy efficiency and rebound effect-Evidence from China's provincial data. *Energy Policy*, 157, 112507. https://doi.org/10.1016/j.enpol.2021.112507

Cui, J., Zhang, J., & Zheng, Y. (2018). Carbon pricing induces innovation: evidence from China's regional carbon market pilots. In AEA Papers and Proceedings (Vol. 108, pp. 453-457). *American Economic Association*. https://www.jstor.org/stable/10.2307/26452781

Cui, J., Wang, C., Zhang, J., & Zheng, Y. (2021). The effectiveness of China’s regional carbon market pilots in reducing firm emissions. *Proceedings of the National Academy of Sciences*, 118(52), e2109912118. https://doi.org/10.1073/pnas.2109912118

Du, Z., Xu, C., & Lin, B. (2022). Does the Emission Trading Scheme achieve the dual dividend of reducing pollution and improving energy efficiency? Micro evidence from China. *Journal of environmental management*, 323, 116202. https://doi.org/10.1016/j.jenvman.2022.116202

Eichhammer, W., & Chlechowitz, M. (2021). *Does the EU Emission Trading Scheme ETS promote energy efficiency?* ODYSSEE-MURE Policy Brief. Fraunhofer Institute for Systems and Innovation Research ISI. Retrieved from https://www.odyssee-mure.eu/publications/policy-brief/ets-promote-energy-efficiency.pdf

EU China ETS. (2025). Train the Trainer. EU-China Dialogue and Cooperation on ETS-related Policies and Measures project. Retrieved from https://www.eu-chinaets.org/index/article/type/training/

EU Delegation to China. (2025). EU-China Dialogue and Cooperation on ETS-related Policies and Measures' project. EU Delegation to China. Retrieved from https://www.eeas.europa.eu/delegations/china/%E2%80%98eu-china-dialogue-and-cooperation-ets-related-policies-and-measures%E2%80%99-project_en?s=166

European Commission (2026). EU trade relations with India. Facts, figures and latest developments. Retrieved from https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/countries-and-regions/india_en

Fais, B., Sabio, N., & Strachan, N. (2016). The critical role of the industrial sector in reaching long-term emission reduction, energy efficiency and renewable targets. *Applied Energy*, 162, 699-712. https://doi.org/10.1016/j.apenergy.2015.10.112

Giacone, E., & Mancò, S. (2012). Energy efficiency measurement in industrial processes. *Energy*, 38(1), 331-345. https://doi.org/10.1016/j.energy.2011.11.054

Goldemberg, J. (2010). Renewable Energy, Energy Efficiency, and Emissions Trading. In *Harnessing Renewable Energy in Electric Power Systems* (pp. 93-110). Routledge. https://ebookcentral-proquest-com.scpo.idm.oclc.org/lib/sciences-po/reader.action?docID=585457&ppg=139&c=RVBVQg

Grubb, M., Poncia, A., Drummond, P., Neuhoff, K., & Hourcade, J. C. (2023). Policy complementarity and the paradox of carbon pricing. *Oxford Review of Economic Policy*, 39(4), 711-730. https://academic.oup.com/oxrep/article/39/4/711/7425306

International Carbon Action Partnership. (n.d.). Indian carbon credit trading scheme. Retrieved from https://icapcarbonaction.com/system/files/ets_pdfs/icap-etsmap-factsheet-125.pdf

International Carbon Action Partnership. (2025a). India notifies emission intensity targets for nine sectors under Carbon Credit Trading Scheme. Retrieved from https://icapcarbonaction.com/en/news/india-notifies-emission-intensity-targets-nine-sectors-under-carbon-credit-trading-scheme

International Carbon Action Partnership. (2026). Emissions Trading Worldwide - Status Report 2026. Retrieved from https://icapcarbonaction.com/system/files/document/260414_icap_sr26_web.pdf

International Emissions Trading Association. (2023). Advancing carbon markets in India. Retrieved from https://www.ieta.org/uploads/wp-content/Resources/Position-and-policy-papers/IETA_AdvancingCarbonMarketsinIndia_2023.pdf

International Energy Agency. (2007). Tracking Industrial Energy Efficiency and CO2 Emissions. Retrieved from https://www.oecd.org/content/dam/oecd/en/publications/reports/2007/06/tracking-industrial-energy-efficiency-and-co2-emissions_g1gh7ecf/9789264030404-en.pdf

International Energy Agency. (2011), Energy Efficiency Policy and Carbon Pricing. IEA, Paris. Retrieved from https://www.iea.org/reports/energy-efficiency-policy-and-carbon-pricing

International Energy Agency. (2020a). Implementing Effective Emissions Trading Systems: Lessons from International Experiences. Retrieved from https://iea.blob.core.windows.net/assets/2551e81a-a401-43a4-bebd-a52e5a8fc853/Implementing_Effective_Emissions_Trading_Systems.pdf

International Energy Agency. (2020b). Sustainable recovery. Retrieved from

https://iea.blob.core.windows.net/assets/c3de5e13-26e8-4e52-8a67-b97aba17f0a2/Sustainable_Recovery.pdf

International Energy Agency. (2023a). Energy Efficiency 2023. Retrieved from https://iea.blob.core.windows.net/assets/dfd9134f-12eb-4045-9789-9d6ab8d9fbf4/EnergyEfficiency2023.pdf

International Energy Agency. (2023b). Countries and Regions: India. Retrieved from https://www.iea.org/countries/india/emissions

International Energy Agency (2023c). Tracking Industry. Retrieved from https://www.iea.org/energy-system/industry

International Energy Agency (2024a). Energy Efficiency 2024. Retrieved from https://iea.blob.core.windows.net/assets/f304f2ba-e9a2-4e6d-b529-fb67cd13f646/EnergyEfficiency2024.pdf

International Energy Agency (2024b). Energy Efficiency 2024: Executive Summary. Retrieved from https://www.iea.org/reports/energy-efficiency-2024/executive-summary

International Energy Agency (2025). Energy Efficiency Policy Toolkit 2025. Retrieved from https://iea.blob.core.windows.net/assets/1c9f0a29-e440-4cbc-839a-9b1916818267/IEAEnergyEfficiencyPolicyToolkit_2025_Online.pdf

Javied, T., Rackow, T., & Franke, J. (2015). Implementing energy management systems to increase energy efficiency in manufacturing companies. *Procedia Cirp*, 26, 156-161. https://doi.org/10.1016/j.procir.2014.07.057

Kukah, A. S. K., Jin, X., Osei Kyei, R., & Perera, S. (2025). Major global carbon emissions trading schemes: a comprehensive review and future directions. *Construction Innovation*. https://doi.org/10.1108/CI-07-2024-0208

Kumar, P., & Agrawal, M. (2024). The Indian carbon market: Pathway towards an effective mechanism. *Centre for Science and Environment*. Retrieved from https://www.cseindia.org/the-indian-carbon-market-pathway-towards-an-effective-mechanism-12328

Lho, S. (2024). The Impacts of K-ETS Auctioning Revenues on Carbon Emissions Reduction and Economic Performance. *Journal of Environmental Policy and Administration*, 32, 27-47. https://doi.org/10.15301/jepa.2024.32.S.27

Liu, J., & Liu, X. (2023). Effects of carbon emission trading schemes on green technological innovation by industrial enterprises: Evidence from a quasi-natural experiment in China. *Journal of Innovation & Knowledge*, 8(3), 100410. https://doi.org/10.1016/j.jik.2023.100410

Misra, K. (2019). Impact of perform-achieve-trade policy on the energy intensity of cement and iron and steel industries in India. *Institute for Social and Economic Change*. Retrieved from https://www.isec.ac.in/wp-content/uploads/2023/07/WP-451-Kaumudi-Misra_2-Final.pdf

Moon, H., & Min, D. (2017). Assessing energy efficiency and the related policy implications for energy-intensive firms in Korea: DEA approach. *Energy*, 133, 23-34. https://doi.org/10.1016/j.energy.2017.05.122

Nitturu, K., Sripathy, P., Yadav, D., Patidar, R., & Mallya, H. (2023). Evaluating Net-zero for the Indian Cement Industry. Council on Energy, Environment and Water (CEEW). Retrieved from https://www.ceew.in/publications/how-can-india-decarbonise-for-net-zero-cement-industry

Oak, H., & Bansal, S. (2022). Enhancing energy efficiency of Indian industries: effectiveness of PAT scheme. Energy Economics, 113, 106220.

Otto, S. (2025) The external impact of EU climate policy: political responses to the EU's carbon border adjustment mechanism. Int Environ Agreements 25, 177–194 (2025). https://doi.org/10.1007/s10784-02509667-z

Pal, K., Mukhopadhyay, J. P., & Bhagawan, P. (2024). Does cap-and-trade scheme impact energy efficiency and firm value? Empirical evidence from India. *Energy Economics*, 134, 107581. https://doi-org.scpo.idm.oclc.org/10.1016/j.eneco.2022.106220

Pan, X., Ai, B., Li, C., Pan, X., & Yan, Y. (2019). Dynamic relationship among environmental regulation, technological innovation and energy efficiency based on large scale provincial panel data in China. Technological Forecasting and Social Change, 144, 428-435. https://doi.org/10.1016/j.techfore.2017.12.012

Park, H., & Hong, W. K. (2014). Korea′ s emission trading scheme and policy design issues to achieve market-efficiency and abatement targets. *Energy Policy*, 75, 73-83. https://doi.org/10.1016/j.enpol.2014.05.001

Park, I., & Yi, D. (2026) Policy Design and Firm-Level Energy Efficiency: Evidence from Emissions Trading versus Command-and-Control in Korea. https://dx.doi.org/10.2139/ssrn.6379653

Press Information Bureau India. (2026). Cabinet approves India's Nationally Determined Contribution (2031-2035) to be communicated to the United Nations Framework Convention on Climate Change. https://www.pib.gov.in/PressReleasePage.aspx?PRID=2245209&reg=3&lang=1

Ray, S., & Bandyopadhyay, K. (2026). Transitioning from PAT to a Carbon Trading System: Implications for India's Iron & Steel, Aluminium Sectors, and Cement under the EU's CBAM (Policy Brief No. 64). *ICRIER*. Retrieved from https://icrier.org/pdf/pb64_Transitioning-from-PAT-to-a-Carbon-Trading-System.pdf

Sahoo, N. R., Mohapatra, P. K., Sahoo, B. K., & Mahanty, B. (2017). Rationality of energy efficiency improvement targets under the PAT scheme in India-A case of thermal power plants. *Energy Economics*, 66, 279-289.

Schlomann, B., & Eichhammer, W. (2014). Interaction between climate, emissions trading and energy efficiency targets. Energy & Environment, 25(3-4), 709-731. https://doi.org/10.1260/0958-305X.25.3-4.70

Sgaravatti, G. (2025). How to fill the remaining gaps in pricing emissions in the EU's energy-intensive industries. Bruegel. Retrieved from https://www.bruegel.org/analysis/how-fill-remaining-gaps-pricing-emissions-eus-energy-intensive-industries

Shrivastava, S., Trivedi, S., & Michael, S. S. (2024). Strengthening India's carbon market: The case for a stability mechanism in India's CCTS. Institute for Energy Economics and Financial Analysis (IEEFA). Retrieved from https://library.edf.org/AssetLink/6328jfn6lw6t8x7yy6q3wkw07x86n6c2.pdf

Singh, N. & Chaturvedi, V. (2023). Understanding Carbon Markets: Prospects for India and Stakeholder Perspectives. New Delhi: Council on Energy, Environment and Water. Retrieved from https://www.ceew.in/publications/indian-carbon-credit-markets-prospects-and-stakeholder-perspectives

Singh, D., & Sharma, A. (2026). How India's final emission reduction targets can shape carbon market dynamics. Council on Energy, Environment and Water (CEEW). Retrieved from https://www.ceew.in/blogs/how-india's-final-emission-reduction-targets-can-shape-carbon-market-dynamics

Sorrell, S., & Dimitropoulos, J. (2008). The rebound effect: Microeconomic definitions, limitations and extensions. *Ecological economics*, 65(3), 636-649. https://doi.org/10.1016/j.ecolecon.2007.08.013

Sripathy, P., Nitturu, K., Yadav, D., & Mallya, H. (2024). Evaluating Net-zero for the Indian Aluminium Industry. Council on Energy, Environment and Water (CEEW). Retrieved from https://www.ceew.in/publications/how-can-india-achieve-low-carbon-sustainable-aluminium-production-and-reduce-carbon-footprint

Tan, X., Wang, R., Choi, Y., & Lee, H. (2024). Does Korea's carbon emissions trading scheme enhance efficiency for sustainable energy and utilities?. *Utilities Policy*, 88, 101752. https://doi-org.scpo.idm.oclc.org/10.1016/j.jup.2024.101752

Tang, R., Guo, W., Oudenes, M., Li, P., Wang, J., Tang, J., ... & Wang, H. (2018). Key challenges for the establishment of the monitoring, reporting and verification (MRV) system in China's national carbon emissions trading market. *Climate Policy*, 18 (106-121). Retrieved from https://www.tandfonline.com/doi/pdf/10.1080/14693062.2018.1454882

United Nations Environmental Program (2024). Bridging the gap: Sectoral greenhouse gas mitigation potentials in 2035. Retrieved from https://unepccc.org/wp-content/uploads/2024/10/sectoral-greenhouse-gas-emissions-reductions-potentials-in-2035.pdf

World Bank Group. (2015). India – Partial Risk Sharing Facility for Energy Efficiency (PRSF) project. Retrieved from http://documents.worldbank.org/curated/en/968091468048913492

World Bank Group (2025). State and Trends of Carbon Pricing 2025. Washington, DC. Retrieved from https://www.worldbank.org/en/publication/state-and-trends-of-carbon-pricing

Worrell, E., Bernstein, L., Roy, J., Price, L., & Harnisch, J. (2008). Industrial energy efficiency and climate change mitigation. *Energy Efficiency*, 1, 548-568. https://link.springer.com/content/pdf/10.1007/s12053-008-9032-8.pdf

Worrell, E., Laitner, J. A., Ruth, M., & Finman, H. (2003). Productivity benefits of industrial energy efficiency measures. *Energy*, 28(11), 1081-1098. Retrieved from https://escholarship.org/content/qt0013f49z/qt0013f49z.pdf

Yahaya, O. A. (2026). Effect of Energy Efficiency Reporting on the Financial Performance of Nigerian Listed Firms. International *Journal of Accounting and Finance Studies,* 11(2), 60-88. http://dx.doi.org/10.13319/ijafs.2026.11.2.60

Zhai, X., Yang, X., Vukovic, D. B., Dinets, D. A., & Liu, Q. (2025). Carbon emissions trading policy and regional energy efficiency: A quasi-natural experiment from China. Energies, 18(5), 1161. https://doi.org/10.3390/en18051161

Zhou, D., Lu, Z., & Qiu, Y. (2023). Do carbon emission trading schemes enhance enterprise green innovation efficiency? Evidence from China's listed firms. Journal of Cleaner Production, 414, 137668. https://doi.org/10.1016/j.jclepro.2023.137668

Annexes

Annex 1: Affiliations and Guiding Questions of Semi-Structured Expert Interviews

This annex outlines the guiding questions used in the semi-structured interviews conducted in March 2026. The questions focused on the transition from energy efficiency-based policies to carbon market mechanisms, with a particular emphasis on implications for industrial energy efficiency. The experts interviewed:

Name	Affiliation	Based
Parth Kumar	Programme Manager, Sustainable Industrialisation Unit, Centre for Science and Environment (CSE)	India
Neelima Jain	Adjunct Fellow, Center for Strategic and International Studies (CSIS); Director, States Initiative, Indian Energy and Climate Center, UC Berkeley	India
Xiaolu Zhao	Senior Director, Climate (carbon markets and climate policy focus)	China

A. Interviews with India-based experts (PAT-CCTS transition)

- *Broad lens:* Transitioning from PAT to CCTS - what does this mean for heavy industry and energy efficiency management in India?
- *Policy lens:* What motivated the shift from PAT's energy-intensity targets to a carbon-intensity cap-and-trade framework under CCTS?
- *Energy efficiency lens:* Do you see a risk that energy efficiency (investment) becomes less central due to this transition from PAT to CCTS?
- *Complementarity lens:* What design elements (e.g. benchmarking, baselines, MRV systems) are most critical to ensure that energy efficiency remains a core pillar of industrial decarbonisation in India under the CCTS?
- *Comparative lens:* What are the experiences and learnings to be drawn for India when looking at other countries that went a similar path, e.g. China, South Korea, Japan?

B. Interview with Xiaolu Zhao (comparative perspective)

- *Broad lens:* What are the main implications for heavy industry when policy frameworks shift from energy-efficiency targets toward carbon-intensity based trading systems? How does this transition affect the role of energy efficiency in industrial decision-making?
- *Policy lens:* From a policymaking perspective, what were the key considerations in China when moving from energy-intensity policies toward an ETS system?
- *Energy efficiency lens:* When carbon-intensity based trading systems are introduced, is there a risk that firms shift away from operational efficiency improvements toward other compliance strategies such as fuel switching?
- *Design lens:* Which policy design elements - such as benchmarking approaches, monitoring and verification frameworks, or complementary efficiency policies - are most important to ensure that ETS systems reinforce rather than weaken incentives for industrial energy efficiency?
- *Comparative lens:* Based on China's experience, what lessons might be relevant for countries such as India that are transitioning from energy-efficiency trading schemes toward broader carbon-intensity based market mechanisms?

Annex 2: Key ETS design variables and their impact on industrial EE outcomes

ETS Design Variable	Description	Impact on Industrial EE
Cap	The total limit placed upon emissions, and the reduction factor (rules that govern its adjustment over time). A key determinant of allowance scarcity. Distinction between absolute cap and intensity-based targets.	Scarcity of allowances increases price and the size of price effects. A high cap reduces more emission, whereas a low cap may fail to keep emission on a net-zero trajectory.
Carbon price	The price per t/CO2e, set by supply-demand mechanics within the carbon credit market	Higher and more predictable prices incentivise EE improvements and decarbonisation investments. Lower or more volatile prices favour short-term compliance strategies, e.g. buying allowances from the market.
Permit allocation	Auctioning: firms bid to purchase permits from a public auction. Free allocation: firms are provided allowances based on their historical emissions, or a determined benchmark.	By forcing companies to purchase permits for their emissions, rather than receive them for free, auctioning strengthens the financial incentives to reduce emissions, reducing the relative cost of abatement policies.
Banking and borrowing	Banking refers to firms' ability to stockpile unused credits for future use. Borrowing, on the other hand, refers to firms' ability to use permits set to be allocated in the future for compliance in the present.	Banking enhances the flexibility of the scheme and supports EE investment planning. Excessive banking or unrestricted borrowing dilutes allowance scarcity and weakens EE incentives.
Implementation timelines	The time horizon over which the scheme is implemented, for example phased tightening of the cap and compliance deadlines.	Provides firms with the opportunity to react to the initiative and prepare for more stringent regulations gradually
Revenue generation	Most ETSs are revenue generating and the ways in which such revenue is spent is a central design component of such schemes. The double dividend hypothesis posits that revenues may finance the removal of other distortionary taxes	Revenues can be allocated to incentivise efficiency, by subsidising green patents, or through financial support for corporate energy management systems.
Monitoring, reporting, and verification (MRV)	Framework for measuring, reporting, and verifying emissions, typically based on standardised methodologies and third-party verification.	Effective MRV mechanisms improve data transparency and help firms identify opportunities for EE improvements.

Annex 3: Review of Chinese pilot ETS schemes and their impact on industrial energy efficiency

China approved seven regional ETS pilots in 2011, which were launched between 2013 and 2014, building on which a final nationwide carbon market, operating on a benchmark- and intensity-based allocation system, entered into force in 2021. In the first phase of pilot programmes, Du et al. (2022) found no positive impact of the ETS on green innovation and efficiency improvement, although the scheme did succeed in lowering carbon emissions. Emissions were reduced largely as a result of fuel switching (Cui et al., 2021) and carbon leakage. Multiple authors also note the unequal impact of the pilot programmes on firms of different sizes, as larger firms have far greater capability to engage in fuel switching and/or carbon leakage through supply chain management (Liu & Liu, 2023). With regards to the 2013 pilot rollout, various investigations have found evidence that ETS schemes incentivised increased technological innovation amongst targeted firms when compared to non-targeted firms, in turn driving efficiency improvements (Chen et al., 2021; Zhai et al. 2025; Liu & Liu, 2023; Pan et al., 2019). Cui et al. (2018) provide deeper insight, demonstrating that the ETS scheme not only increased the total number of green patents, but that the share of green patents among total patents filed also increased. Chen et al. (2021) and Pan et al. (2019) also note the increasing differential in efficiency improvements between targeted and non-targeted forms as the policy progressed. This long-term impact is further supported by Zhai et al.'s (2025) observation of the "shock-enhancement-stability" pattern, noting a high effect on firms' energy efficiency immediately after the policy announcement, followed by a period of enhancement and eventual stabilisation of efficiency improvements. Observation of the "shock" effect is further supported by Liu & Liu's (2023) finding that innovation increased among a number of targeted firms prior to the formal implementation of the policy. Zhai et al (2025) identify three mechanisms through which the ETS pilot programmes led to efficiency improvements. First, targeted firms filed more green patents and subsequently received more government subsidies for EE-related R&D. Second, the ETS pilots strongly incentivised firms to switch to less carbon-intensive fuels. Third, the pilot schemes strengthened regulatory commitment and political attention to emissions reductions due to the necessary role of local governments. Zhou et al. (2023) also find evidence of increased green innovation, further positing that higher liquidity in carbon markets works to reinforce innovation incentives. Additionally, Cui et al. (2018) note that higher carbon prices also increase innovation and efficiency outcomes. Despite these benefits, however, Chen et al. (2021) highlight the impact of the rebound effect (efficiency improvements leading to price reductions, which incentivise higher consumption levels) in offsetting the gains instigated by the ETS.

Annex 4: Review of Korean ETS scheme and its impact on industrial energy efficiency

Korea's ETS system was launched in 2015, covering seven major sectors including industry and power. In 2022, the scheme accounted for roughly 79% of Korea's total emissions and six key GHGs. Permit allocation is conducted through a combination of free allocation via benchmarking, and auctioning - the share of which has gradually increased as the scheme has progressed. Phases I and II (2015 - 2020) saw little to no allocation through auctioning, however phase III (2021) implemented a minimum requirement that 10% of permits in a given sector be allocated through auctions (with certain exceptions). Regarding the impact of the scheme on industrial energy efficiency, investigations have found little evidence of efficiency improvement (Tan et al., 2024; Moon & Min, 2017). Park & Yi (2026) find positive impacts in the years immediately after implementation, however the effect is shown to decrease or disappear by phase III. Possible reasons for this include the predominance of free allocation in the early phases of implementation (Park & Hong 2014), and lack of mechanism for allocating revenues into climate or energy efficiency initiatives (Lho, 2024). The positive impact of the ETS on industrial efficiency also appears to be more pronounced in larger, more profitable firms, with greater access to capital and capacity to implement meaningful improvements (Park & Yi, 2026). In addition, two characteristics specific to Korea have been found to inhibit the effectiveness of the Korean ETS and the achievement of related efficiency improvements. A high share of emissions covered under the ETS can be attributed to a small number of major emitters, which creates an oligopolistic market structure with low liquidity, removing the incentive for firms to invest in energy efficiency (Park & Yi, 2026). Furthermore, the Korean government's direct regulation of electricity prices prevents the carbon price from being passed onto industrial firms, dampening market signals (Park & Hong, 2014).

Annex 5: Comparison of PAT and CCTS policy design

Feature	PAT	CCTS
Launch year	2011	2023
Objective	Improve energy efficiency	Reduce carbon intensity to align with India's NDCs and net-zero goals
Unit of credit measurement	Tonnes of oil equivalent (TOE)	Tonnes of CO2 equivalent (tCo2e)
Compliance cycle	3 years	1 year
Entity	Designated Consumers (DC)	Obligated Entity (OE)
Certificate	Energy Saving Certificates (ESCerts)	Carbon Credit Certificates (CCCs)
Issuance of certificates	Ex-post	Ex-post
Monitor and verification	Accredited Energy Auditors	Accredited Carbon Verifiers
Target	Unit-wise	Unit-wise
Administrator	Bureau of Energy Efficiency	Bureau of Energy Efficiency
Trading regulator	Central Electricity Regulatory Commission	Central Electricity Regulatory Commission
Number of sectors covered	13 (energy-intensive industries)	9 (broader coverage expected in the future)
Numbers of entities covered	1,333 (all cycles)	740 (expected number once all nine industries are notified)
Penalty for non-compliance	1 million INR + the value of the energy savings not obtained by the DC, measured in toe	Twice the average CCC market price
International linkage	None	Joint Crediting Mechanism (JCM) with Japan under Article 6.2

Annex 6: Number of Designated Consumers (DCs) by Sector and PAT Cycle

Sector	PAT Cycle I (Apr 2012)	PAT Cycle II (Apr 2016)	PAT Cycle III (Apr 2017)	PAT Cycle IV (Apr 2018)	PAT Cycle V (Apr 2019)	PAT Cycle VI (Apr 2020)	PAT Cycle VII (Apr 2022)	Total Notified DCs
Aluminium	10	12	1		1		12	14
Cement	85	111	14	1	12	37	120	175
Chlor-Alkali	22	24		2	2		24	28
Fertilizer	29	37					0	37
Iron & Steel	67	71	29	35	23	5	134	204
Paper & Pulp	31	29	1	2	8	2	24	48
Textile	90	99	34	7	16	7	120	168
Thermal Power Plants	144	154	37	17	17		152	239
Refinery		18				20	0	20
Railways		22					26	26
DISCOMs		44					95	96
Petrochemical				8			0	8
Buildings				37	31	64	0	133
Total	478	621	116	109	110	135	707	1196

Note: Blank cells indicate that the sector was not included in the respective PAT cycle. Authors' own illustration. Data source: BEE (2023)

Annex 7: Overview of academic studies on the effectiveness of the PAT scheme

Author(s)	Year	Journal / outlet	Sector	PAT cycle / years studied	Methodology	Key findings
Bhandari & Shrimali	2018	Renewable and Sustainable Energy Reviews	PAT broadly / multi-sector	Cycle I	Qualitative effectiveness analysis	Conclude PAT targets were not strict enough to be additional, long-term EE investment may not occur, the ESCert market may not properly form, equity issues remain
Sahoo, Mohapatra, Sahoo & Mahanty	2017	Energy Economics	Thermal power plants	Cycle I	Data Envelopment Analysis (DEA) on plant efficiency and saving potential	Finds PAT targets for thermal power are lower than actual potential; estimates that if full potential were realized the market could see a surplus of 4.7 million ESCerts from the thermal power sector alone.
Oak & Bansal	2022	Energy Economics	Cement, fertilizer, pulp & paper	Cycle I, using firm data from 2005-2015	Firm-level difference-in-differences with fixed effects	PAT reduced energy intensity by 2.7% in cement and 1.6% in fertilizer, but had no significant additional effect in pulp & paper.
Pal, Mukhopadhyay & Bhagawan	2024	Energy Economics	Six industries: textile, paper & pulp, cement, chlor-alkali, iron & steel, aluminium	Cycle I, using data 2006-2015	DID + Propensity Score Matching on firm-level financial and energy-consumption data	Finds no statistically significant impact on energy efficiency.
Chauhan & Thangavel	2025	Energy Policy	Iron & steel	Cycles I and II, with firm data 2004-2019	Two-way fixed-effects DID	Finds PAT reduced energy intensity in iron & steel by 1.7%.
Chauhan & Mohanasundari	2025	Energy Sources, Part B: Economics, Planning, and Policy	Pulp & paper	Cycle I, with firm data 2002-2019	Firm-level DID with firm and year fixed effects	Finds PAT participation reduced energy intensity in pulp & paper by 13.1% relative to non-regulated firms. Effects are stronger for private and large firms.
Chauhan & Thangavel	2025	Economic Affairs	Textile	Panel spans 2002-2022	Two-way fixed effects panel model	Finds energy intensity declined by 3.9% due to PAT.
Misra	2019	ISEC Working Paper	Cement; Iron & Steel	Cycle 1	Firm-level difference-in-differences	Finds no statistically significant reduction in energy intensity due to PAT in cement and iron & steel.