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Market solutions for decarbonising supply chains in the chemical industry

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Complex supply chains pose an enormous challenge for decarbonising the chemical industry in the face of pressure to move towards net-zero emissions. We argue that transparency, traceability and end-to-end governance can incentivise companies to invest in verified emissions reductions within their own value chains.

Chemical companies constitute one of the most carbon-intensive industries, responsible for approximately 5-6% of global annual greenhouse gas emissions[1,2]. These companies are under pressure from regulators—particularly in relation to the EU Carbon Border Adjustment Mechanism—investors, and civil society. The challenge for balancing emissions with greenhouse gas removal lies in cutting emissions across complex, globally dispersed supply chains, which account for most of the industry's climate impact.

Chemical companies in some regions, such as Germany, have made good progress in their decarbonisation goals, thanks to green hydrogen and heat integration technologies[3], global efforts remain uneven. In particular, Asia is falling behind Europe and the US as a result of less stringent carbon tax policies and emission accounting practices[3,4]. This slow pace of decarbonisation, referring to the limited deployment of low-carbon technologies at scale, is caused by the cost of infrastructure and the long lifetime of its equipment, which lasts decades. To accelerate progress, new approaches need to achieve three goals: link emissions cuts directly to production; reward low-carbon innovation; and foster cooperation across global supply chains. Market-based insetting solutions, that is, mechanisms that enable companies to invest in verified emission reductions within their own operations or their value chain, can offer a powerful path forward. Recent studies[5,6] show that insetting helps to decarbonise supply chains (e.g., ammonia and methanol) and can deliver up to 17% emission reductions.

The feasibility of this insetting framework is further supported by the outcomes of the recently held COP30 in Belém, where the focus shifted from setting targets to technical implementation. For example, the Article 6 Ambition Alliance under the Paris Agreement[7] was launched to encourage governments and private sectors to engage in high-integrity crediting activities to further reduce their emissions. This initiative aims to narrow the gap between existing Nationally Determined Contributions and the Paris Agreement temperature goals. The Article 6 Ambition Alliance also promotes transparency, robust accounting, and alignment with long-term low-emission strategies, which are principles that resonate with the insetting framework proposed here. Interest in insetting has grown, but its implementation in the chemical industry lags behind expectations because supply chains are complex and heavily reliant on fossil feedstocks. Methodological gaps, weak governance, and immature markets add to the challenge. These barriers can and must be overcome. Robust frameworks and closer supplier connections can speed up emission cuts, enhance resource use, and strengthen resilience.

We argue that the chemical industry can overcome these obstacles with three interconnected solutions (see Fig. 1): (1) harmonised and transparent accounting frameworks, (2) digital systems to track and verify reductions, and (3) collaborative governance and capacity building across the value chain. With these strategies, we can transform insetting from a promising concept into a functional market mechanism to decarbonise the chemical industry.

Harmonised and transparent accounting frameworks

We lack globally standardised frameworks for measuring, reporting, and verifying emissions reductions. There is currently no internationally accepted accounting standard for how insetting reductions should be measured, attributed, and claimed within chemical value chains. Without clear standardised frameworks, we are at risk of double-counting, inconsistent calculation of emission reductions, and unverifiable claims that impede investment and slow adoption.

Chemical value chains are inherently complex. One tonne of ethylene may pass through multiple intermediate transformations before reaching a consumer product in some form. Ownership of reductions achieved through carbon capture, bio-feedstock substitution, or process electrification is far from straightforward. This makes it impossible for companies to credibly claim or independently monetise Scope 3 reductions, that is, reductions under common greenhouse gas accounting standards applied across the value chain.

The sector must converge around interoperable and science-based accounting frameworks aligned with international standards, particularly the Enhanced Transparency Framework of the Paris Agreement[8]. To ensure corporate insetting data is robust enough to inform national Biennial Transparency Reports[9], a credible insetting system requires: (i) standardised allocation methodologies to apportion emission reductions across multiple outputs and actors; (ii) clear rules on timing and location for emission reduction claims, ensuring they reflect recent actions within the same value chain and cannot be shifted across unrelated geographies or periods (iii) transparent retirement rules, ensuring each emission reduction claim can only be used once.

We recommend a certificate-based chain-of-custody model that allows upstream producers, such as ethylene plants using carbon capture storage, to issue verified digital certificates for emission reductions measured against standardised baselines[10]. These certificates can then be purchased and retired by downstream buyers to reflect Scope 3 improvements without requiring physical segregation of materials. This approach also ensures that the total quantity of reductions claimed does not exceed the actual reductions achieved.

To enhance interoperability, cross-sector alignment is crucial. Experience from such formal market instruments as Guarantees of Origin

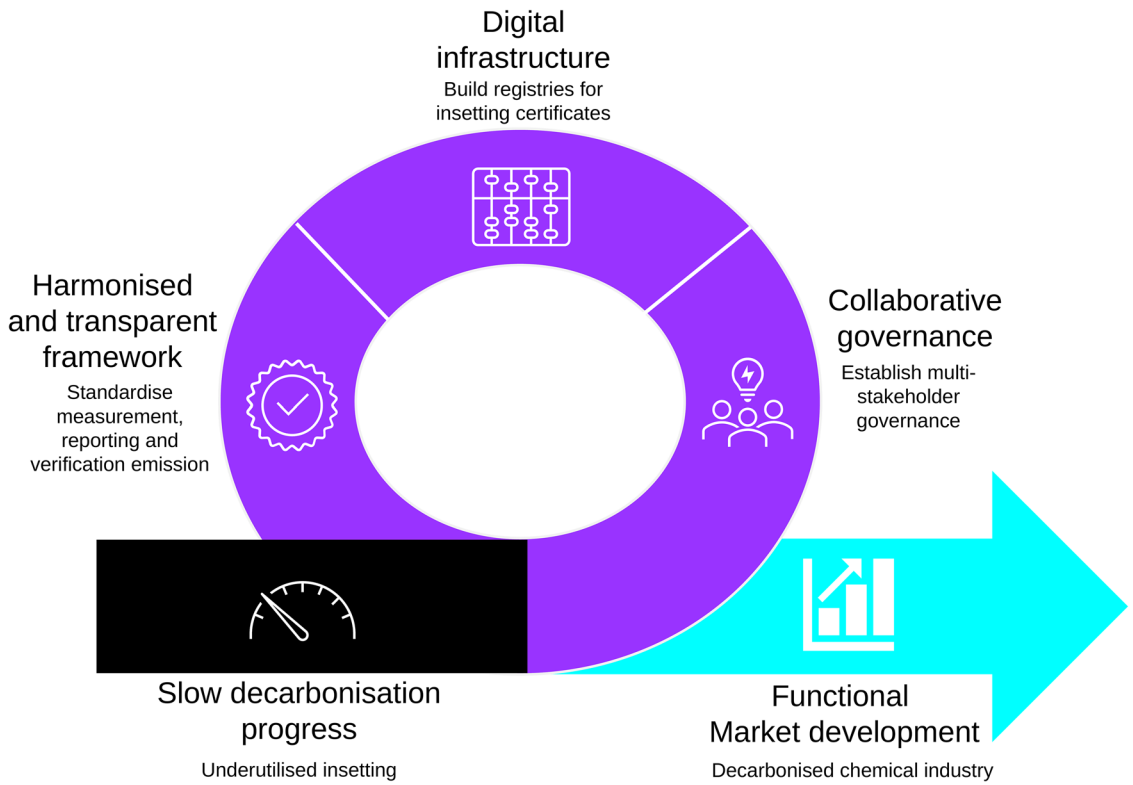


Fig. 1 | Decarbonisation of the chemical sector through insetting-enabled market mechanisms. The figure illustrates how the current slow and fragmented decarbonisation trajectory of the chemical sector (black) can be accelerated through the introduction of coordinated market-based insetting mechanisms (blue), supported by harmonised accounting frameworks, digital traceability systems, and collaborative governance across the value chain. These enabling elements help link emissions reductions directly to production and procurement decisions, improve transparency and verification, and align incentives among upstream and downstream actors. Together, they enable a transition towards a more scalable, credible, and investable decarbonisation pathway (green), in which verified emissions reductions are integrated into supply-chain decision-making and contribute to sustained emissions performance improvements.

for renewable energy and Sustainable Aviation Fuel Certificates for the aviation sector[11] shows that market confidence depends on clear criteria to verify reductions, to ensure that they result from actions beyond business-as-usual, and to guarantee their permanence. At COP30, the Low-Emission Ammonia-based Fertiliser initiative was launched to create certifiable emissions reductions in fertiliser value chains by linking low-emission hydrogen and ammonia production to downstream agricultural demand[12]. The initiative brings together producers, governments, financiers, and standards bodies to establish shared baselines, verification rules, and market signals for low-carbon fertilisers. This mirrors the insetting logic proposed in this paper: emissions reductions are generated upstream (e.g., via green hydrogen or carbon capture and sequestration-enabled ethylene), digitally certified, and claimed downstream without requiring physical segregation of products. Low-Emission Ammonia-based Fertiliser initiative demonstrates that certificate-based, value-chain-specific instruments can be implemented at scale in chemically intensive sectors.

Finally, regulatory bodies should formally recognise insetting within established compliance frameworks such as the European Union Carbon Border Adjustment Mechanism or the Corporate Sustainability Reporting Directive. To ensure global relevance, the insetting framework must adapt to diverse policy environments, while the European Union's Carbon Border Adjustment Mechanisms provides a robust regulatory signal. For example, US tax credits under the Inflation Reduction Act (specifically for carbon capture and green hydrogen) can serve as the financial baseline for verifying the "additionality" of emission reduction certificates. Similarly, China's "Dual Carbon" goals (peaking emissions before 2030 and achieving carbon neutrality by 2060) offer a massive scale for sector-wide insetting platforms, provided digital registries are interoperable with China's national emissions trading scheme. These measures align with COP30's emphasis on inclusivity and transparency, ensuring that insetting evolves as a globally adaptable mechanism rather than a region-specific solution[12]. Such recognition would ensure that claims are not merely voluntary marketing tools but credible, reportable instruments of decarbonisation.

Digital market infrastructure and traceability

Without the infrastructure to operationalise it, even the strongest accounting framework will fail. There is currently no publicly accessible unified registry to track, verify, and exchange insetting certificates, and data on emission reductions is fragmented across businesses and incompatible systems. This digital gap prevents market formation. Stakeholders cannot have faith that reported reductions match confirmed activities in the absence of dependable, impenetrable infrastructure. Additionally, fragmentation restricts scalability, discourages small and medium-sized suppliers, and increases transaction costs.

The creation of interoperable digital registries for emission reduction claims is the linchpin of a functioning insetting market. Such systems would record every step in the lifecycle of a reduction claim—from issuance and

transfer to final retirement—ensuring full traceability, auditability, and transparency. We propose four phases of market evolution:

1. Proprietary Tools (2026–2027): Companies develop internal carbon accounting systems, often spreadsheet-based and isolated.
2. Industry Platforms (2027–2029): Industry collaborations can create shared rulebooks and data formats.
3. Interoperable Infrastructure (2029–2030): Multiple registries converge under common protocols, supported by regulatory linkage to established compliance frameworks such as the European Union Carbon Border Adjustment Mechanism or the Corporate Sustainability Reporting Directive.
4. Embedded Market Mechanism (2031 onward): Digital emission reduction claim platforms become integral to procurement, finance, and reporting systems.

In order to have robust platforms, we need to design them with interoperability, granularity, auditability, data sovereignty, market integration, and security in mind. Technologies such as blockchain for secure transactions, digital twins for real-time process simulation, and AI-driven systems for automated measurement and verification can help reduce errors and build trust.

The digital ecosystem must ensure that carbon metrics are interpreted consistently across systems while allowing businesses to maintain control over sensitive operational data.

COP30 also launched a Plan to Accelerate Solutions on Sustainable Chemicals and Materials, which, together with the Open Coalition for Compliance of Carbon Markets[12], explicitly targets harmonised regulatory frameworks and traceable low-carbon feedstocks. While The Plan to Accelerate Solutions focuses on the sectoral demand for chemicals, the Open Coalition provides the horizontal market infrastructure, which is interoperable data systems and high-integrity accounting, required to verify those claims. These early deployments provide real-world validation that market-based mechanisms for chemical decarbonisation are no longer theoretical but already entering policy-supported implementation. Financial innovations have the potential to accelerate adoption. Early investment can be made less risky through support from philanthropic or development finance institutions, while initial infrastructure funding can come from mechanisms such as performance-based carbon contracts, green bonds, or reinvestment of revenues from emissions trading programs. Transparent registries, reliable measurement and verification technology, and innovative financing models can help the industry move from pilot projects to a mature insetting market where verified emission reductions are treated as valuable assets rather than administrative obligations.

Collaborative governance and capacity building

More than just technical systems are needed for insetting; trust-building governance across disjointed global value chains is also necessary. Because of the diversity of the chemical industry, no one actor can set rules or restrict participation. Rather, cooperative, flexible governance models need to develop in step with the maturity of the market. The current efforts are dispersed among several pilot projects, voluntary standards, and consortia. Smaller businesses often lack the finances to participate, and there is a lack of neutral coordination that fosters mistrust. Furthermore, varying regional regulations, such as carbon pricing schemes in Europe and tax incentives in the United States, add uncertainty and compliance risk.

Multi-stakeholder governance structures that combine accountability and flexibility must be established. We propose three evolutionary phases[13]:

1. Initiation: High-trust bilateral pilots to produce data and test frameworks.
2. Growth: Neutral orchestrator is appointed to coordinate protocols and manage shared infrastructure, such as an industry association or standards body.
3. Consolidation: Formal regulation and international alignment that guarantees consistency, inclusivity, and enforcement.

To succeed, governance should embed two-tiered incentives: system-level rewards, such as preferential access to low-carbon markets or reduced compliance costs, and participant-level value, including new revenue streams or reputational benefits.

Policy alignment enhances governance integrity. Governments can accelerate progress by (i) recognising insetting in national procurement mandates and climate strategies; (ii) creating controlled pilot programs to test regulatory integration; and (iii) offering tax incentives for verified supply chain emission reductions.

A concentrated public-private approach will ensure that insetting develops as a proper complement to compliance markets, rather than as a competitor system in which investors, regulators, and industry consortia share governance responsibilities.

Beyond the blueprint: managing risks and counterarguments

While the case for insetting is strong, its credibility rests on how it is done. Without proper oversight, insetting could result in symbolic decarbonisation, where companies purchase certificates instead of actually reducing emissions. This risk can be avoided by ensuring every certificate is tied to reductions that are verifiable, result from actions beyond business-as-usual, and are permanent, supported by transparent measurement and independent audits.

Another concern is that of equity and participation. Complex certification systems are out of reach for smaller players, while large multinational corporations can afford them. Any such design needs to ensure equitable access through mechanisms such as (i) shared verification services where a neutral platform pools measurement and verification for multiple suppliers, (ii) subsidised onboarding supported by buyer coalitions, development finance, or small levies on certificate transactions, and (iii) accessible digital tools where small players reach standardised data templates, automated checks which reduce administrative burden. Similar cost-reducing models are already used in established carbon market frameworks[14]. Notably, the United Nations Clean Development Mechanism Program of Activities[15] allows large numbers of small, dispersed activities to be incorporated under a single governance and verification framework. By centralising oversight while decentralising participation, such models lowered transaction costs and enabled broad-based engagement without compromising credibility. This provides a relevant precedent for inclusive insetting market design for the chemical sector.

Low-and middle-income countries (LMICs) should not be left behind as well. The insetting framework must proactively address the structural barriers facing LMICs, where high capital costs and limited technical infrastructure often stall decarbonisation efforts. Rather than becoming a barrier to trade, insetting systems can be designed to lower entry hurdles through 'North-South' technology transfer and capacity-building governance. This involves multinational chemical leaders providing digital infrastructure and verification services to upstream suppliers at subsidised rates, supported by blended finance models. By combining development finance, buyer coalitions, and concessional loans to fund digital infrastructure, these programs can align with UNFCCC and COP30 initiatives[12]. Such a design

ensures interoperability with Article 6 mechanisms and voluntary carbon markets, transforming insetting from a localised compliance tool into a global market mechanism that prevents carbon leakage while fostering equitable industrial growth in developing economies.

Lastly, integrating insetting with existing carbon markets requires caution. Insetting should complement rather than weaken external offset programs or compliance systems. In practice, this means that companies should continue to prioritise operational decarbonisation measures such as improving process efficiency, fuel switching etc., before making any market-based claims. Insetting can then be used to support verified emission reductions within a company's value chain, where direct abatement is not immediately feasible, which is in line with science-based target initiative frameworks[16]. This would strengthen the credibility of companies' strategies while avoiding over-reliance on market claims. Consistency depends on aligning rules so that emission reduction claims are recognised across frameworks without being counted twice.

In the end, these disclaimers broaden the case for insetting, rather than lighten it. Insetting can close the gap between systemic change and corporate ambition through transparent data systems, inclusive governance, and regulatory alignment.

Reducing emissions within a chemical company's own value chain has the potential to provide an authentic means for the chemical industry to turn climate ambition into measurable and market-driven action, while linking up-and downstream players seamlessly. A trusted system that combines rigorous standards with digital transparency and collaborative governance can help turn Scope 3 decarbonisation from an administrative burden into a competitive advantage that makes low-carbon growth both profitable and unavoidable.

Data availability

All data are available in the main text and supplementary material.

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Competing interests

The authors declare no competing interests.

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