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Regulation and Markets
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MAY 2026

PROJECT-BASED CARBON CREDIT MARKETS

OVERVIEW, ISSUES, AND FUTURE DIRECTIONS

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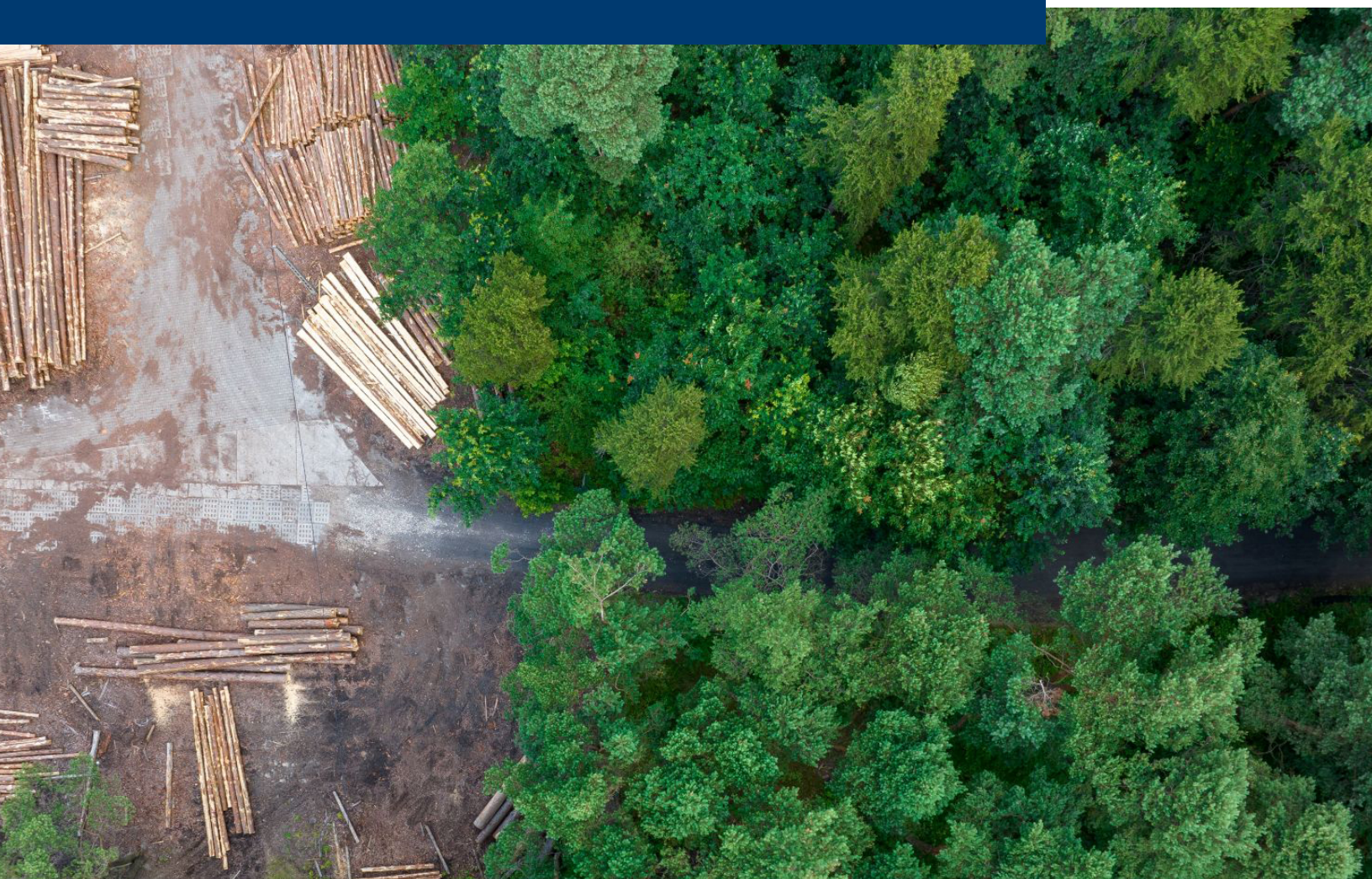

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DISCLOSURES

Broekhoff advises Calyx Global and the ICVCM under paid contracts with his employer, the Stockholm Environment Institute. These organizations did not review this work prior to publication. The analysis and conclusions presented here are solely those of the authors.

This paper is part of a workstream made possible by support from Bloomberg Philanthropies. The views expressed in this report are those of its authors and do not represent the views of Bloomberg Philanthropies, their officers, or employees.

Executive summary

In the past three decades, carbon credit markets have emerged as a prominent mechanism for channeling finance into climate change mitigation projects around the world. Carbon credits are generated by a diverse array of activities that avoid or remove greenhouse gas emissions from the atmosphere, including renewable energy, nature-based projects such as reforestation or avoided deforestation, and engineered removals like direct air capture. Nearly 6,000 companies globally use carbon credits to meet voluntary climate commitments, and dozens of governments recognize them for meeting compliance obligations under regulatory carbon pricing programs. While carbon credit markets remain small compared to global needs for climate finance, they hold considerable potential for mobilizing private investment to achieve global climate and energy transition goals.

Despite their potential, carbon credit markets have suffered from persistent challenges. Multiple studies have found that many credits fail to correspond to additional, accurately quantified, and permanent mitigation (see Glossary for definitions). This points to broader structural issues in these markets that have yet to be fully addressed. Lack of transparency and informational asymmetry subdue demand and amplify public distrust, while weak crediting standards open the door to adverse selection. Carbon credit markets also face perennial concerns about whether they detract from higher-priority mitigation objectives or discourage implementation of more effective policy measures. These concerns have existed for years, and experience suggests they are unlikely to go away entirely. Carbon credit markets have been designed to serve multiple objectives—including supporting specific constituencies and delivering regulatory cost containment—which typically entail tradeoffs with respect to environmental performance.

However, ongoing quality issues do not mean these markets are not useful. Rather, they need to be developed and regulated with their challenges in mind and with an eye to whether they can advance climate policy objectives. To deliver on their potential, carbon credit markets require institutions capable of safeguarding environmental performance, providing transparency, and managing the tradeoffs inherent in aligning markets with broader policy goals. New oversight bodies, such as the Integrity Council for the Voluntary Carbon Market (ICVCM), and new rating agencies are attempting to restore market confidence through stricter "high-integrity" labeling exercises, while parallel initiatives are policing responsible use of carbon credits. Other initiatives, like the expansion of buyers' coalitions aimed at driving sectoral transitions (like the LEAF Coalition) and organizations aimed at improving data-transparency (like the Climate Action Data Trust) are laying further groundwork for effective markets.

Continued government support for initiatives to enhance integrity and build market infrastructure will be crucial for ensuring markets work to deliver on mitigation goals. Governments are uniquely positioned to enforce integrity guardrails and deter abuse, clarify acceptable claims, and align voluntary and compliance markets with broader policy objectives. Governments can also help drive greater alignment under Article 6 of the Paris Agreement, enabling further global cooperation. If supported with a focus on integrity, transparency, and clear objectives in mind, project-based carbon credit markets can continue to play an important role in driving decarbonization and channeling climate finance to communities in need.

This paper explains and evaluates project-based carbon credit markets—assessing their economic logic, empirical performance, and the emerging and potential reforms to ensure they contribute meaningfully to achieving climate goals. We discuss the history of carbon credit markets, their current challenges, and key areas for future development.

THE ORGANIZATION OF THIS PAPER

This paper is organized in three parts, and readers may wish to approach them differently depending on their familiarity with carbon credit markets. **Part 1: What are project-based carbon credits?** introduces the basic concepts underlying project-based carbon credits and reviews the historical development of these markets. Readers already familiar with this background may wish to proceed directly to **Part 2: Overview of current carbon credit markets,** which provides an assessment of how these markets function today, including key challenges and emerging responses. **Part 3: Future directions** considers possible policies to improve the effectiveness and credibility of carbon credit markets.

Part 1: What are project-based carbon credits?

INTRODUCTION

Climate change is widely understood as a market failure—arising because markets do not adequately price the negative effects of greenhouse gas emissions (GHGs) or the benefits of environmental protection. In response to these failures, governments intervene in markets using a variety of policy tools, which, in the case of climate change, range from carbon pricing—requiring firms to pay for their emissions—to direct regulation, such as mandated clean production standards. A substantial body of empirical research shows that well-designed carbon pricing and regulation can reduce emissions without undermining economic growth, making these policies central to any credible climate strategy (Döbbeling-Hildebrandt et al. 2024; Colmer et al. 2024; Metcalf and Stock 2020).

Yet, there are times when these government interventions may not be economically, politically, or practically feasible. In some sectors—such as agriculture and small-scale industries—emissions are diffuse and costly to monitor. In many developing countries, limited administrative capacity can complicate the implementation of carbon pricing regimes. Even where policies are technically feasible, political resistance can prevent their adoption—as demonstrated by repeated failures to establish a carbon price in the United States (Chemnick 2020). In these contexts, countries can leverage complementary, market-based mechanisms to address climate change.

Carbon credit markets are one such mechanism. Unlike with a carbon tax, where GHG-emitting companies pay a regulatory fee to the government, in carbon credit markets, buyers fund pro-climate projects (e.g., reforestation or carbon capture) through the purchase of carbon credits, which represent emissions that the project helped avoid or remove from the atmosphere. The environmental benefits of these markets are conceptually straightforward: They finance projects that help mitigate climate change. Buyers benefit too, as they can use credits to advance voluntary climate pledges or comply with environmental regulations in a flexible, cost-effective manner. Today, these buyers represent some of the largest companies in the world, with almost half of Fortune 500 companies committed to purchasing carbon credits (Morales 2024). From 2015 through 2024, more than 3 billion carbon credits were issued globally, each representing one ton of carbon dioxide equivalent (CO_2e) emissions (World Bank 2025).

While the scale of these markets remains modest relative to global emissions, properly designed carbon credit markets serve several distinct objectives, which can complement traditional climate policies:

- Channeling investment: One major role these markets can play is mobilizing capital for mitigation activities. This is particularly salient in developing countries, where projects may otherwise lack access to financing, and where projects can deliver multiple sustainable development benefits. Even in industrialized nations, ambitious climate commitments often outpace the availability of public dollars, and carbon credit markets can help supply additional private funding.
- Cost containment: Carbon credit markets also can enhance cost-effectiveness by enabling mitigation where it is least expensive. Firms facing high abatement costs may purchase credits from projects that avoid or remove emissions more cheaply, thereby lowering the overall cost of achieving an emissions target. For individual firms, this is a highly attractive feature of carbon credit markets, and in some cases it can help them meet their compliance obligations (e.g., government-imposed emissions caps) cost effectively.
- Coalition building: The above objective also provides important political benefits. By lowering the cost of complying with climate policies, governments can support critical business sectors while nurturing coalitions that improve long-term policy durability.

These markets are not without controversy. Concerns about credit quality—that is, whether credits do in fact

represent the mitigation outcomes that buyers claim—have raised doubts about their efficacy. Critics also argue that overreliance on credits may deter buyers from making necessary investments in reducing their own emissions. As a result, some observers have questioned whether carbon credit markets should play a role in climate policy at all (Macintosh et al. 2025a; Cullenward et al. 2023).

The relevant question, however, is not whether carbon credit markets are perfect, but whether they can be designed and governed in ways that facilitate real mitigation and contribute meaningfully to policy objectives. These markets have become a key tool for leveraging mitigation opportunities, and ensuring they work effectively will be essential for achieving global climate and energy transition goals. This paper explains and evaluates carbon credit markets with that objective in mind.

PROJECT-BASED CARBON CREDITS, EXPLAINED

Carbon credits are tradable instruments that represent an exclusive claim to GHG emissions avoided or removed from the atmosphere. Credits are issued to project developers who avoid or remove GHG emissions. Credits can then be sold to buyers in both voluntary marketplaces (e.g., airlines offering customers to offset their emissions) and compliance marketplaces (e.g., the California cap-and-trade program). After purchase, buyers can "retire" credits and remove them from circulation to count towards climate mitigation goals. To prevent double counting, only retired credits can be claimed as valid mitigation. Buyers can also choose to hold unretired credits to trade speculatively or bank towards future compliance requirements or voluntary commitments.

Project developers can generate carbon credits from a variety of activities that avoid or remove GHG emissions (Broekhoff et al. 2024). Common types include:

- Renewable energy developments (such as wind, solar, and hydro) that avoid fossil fuel emissions
- Improvements to industrial processes (such as N_2O destruction and hydrofluorocarbon reclamation) that reduce GHG leakage
- Nature-based projects (such as deforestation prevention, reforestation, and improved forest management) that avoid emissions from land use change or sequester carbon in biomass
- Household and community projects (such as clean cookstove distribution or community biodigesters) that reduce energy demand
- Engineered removals (such as direct air capture and biochar production) that remove carbon from the atmosphere and store or bind it. (For a more comprehensive list of project types, see Appendix A)

In addition to projects (which are the focus of this paper), carbon credits can also be generated from large-scale programs that drive emission reductions across an entire country or province. Currently, such programs are limited to those that avoid emissions from tropical deforestation and are typically implemented by governments.[1]

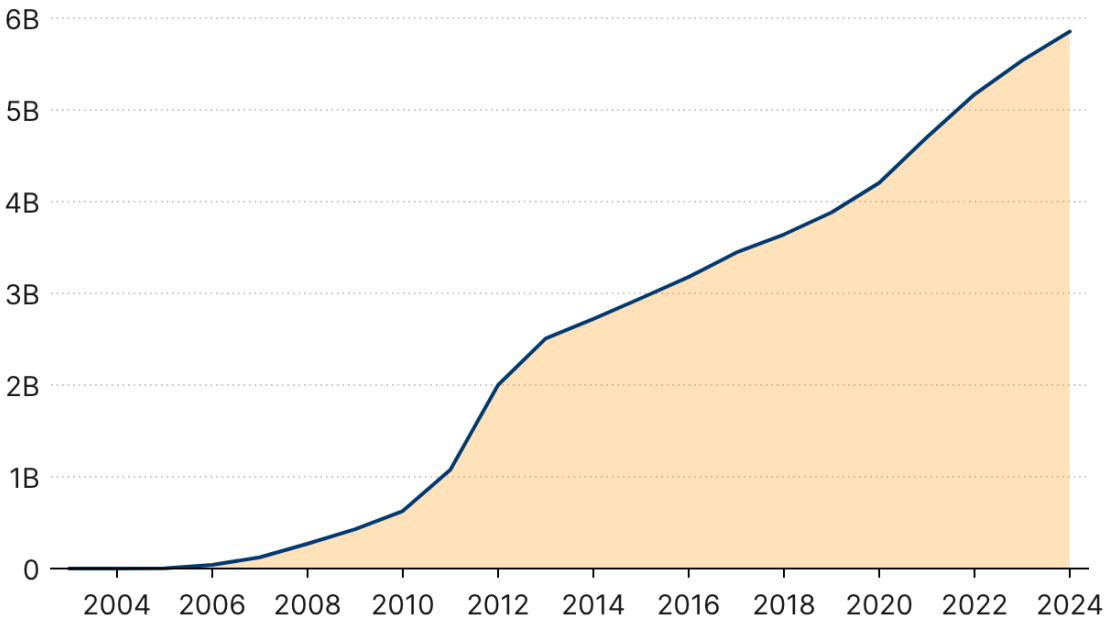
In 2023 alone, nearly 6,000 companies purchased carbon credits to meet voluntary climate commitments (Wetterberg et al. 2025). In 2024, global spending in the voluntary carbon market (VCM) exceeded $500 million (Forest Trends' Ecosystem Marketplace 2025). Meanwhile, 24 government-run emissions trading systems (ETSs)—collectively covering nearly 20% of global emissions—allow for carbon credits to be retired as compliance options (World Bank 2025; ICAP 2025). At the international level, Article 6 of the Paris Agreement has established a system for countries to trade carbon credits to meet their nationally determined contributions (NDCs). As shown in Figure 1, cumulative carbon credit issuances have grown substantially over the last two decades to reach nearly 6 billion tons by 2024.

WHAT IS CARBON OFFSETTING?

Carbon credits were originally designed as a tool for carbon offsetting. Offsetting allows credit buyers to meet emissions limits in a flexible way. Under a cap-and-trade system, for example, regulators set a cap on how much certain sources—like power plants—can emit. A cap set at or below what they would otherwise produce would lead to fewer emissions overall. With off-

FIGURE 1

Cumulative Carbon Credit Issuances, 2003-2024 (Tons CO_2e)



Source: World Bank, Carbon Pricing Dashboard

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setting, regulated sources can emit more than their cap allows if they pay for emissions reductions (or carbon removals) elsewhere. These reductions outside the cap are meant to balance out, or "offset," the excess emissions from capped sources, so total global emissions remain unchanged from what they would have been if capped sources had reduced emissions directly. This idea was first used in U.S. air pollution policy. A 1977 amendment to the Clean Air Act allowed power plants to exceed local pollution limits if they paid other facilities to reduce more of the same pollutant (Gillenwater 2012). Internationally, carbon offsets became formal compliance tools under the 1997 Kyoto Protocol, which allowed countries to use tradable carbon credits to meet their binding GHG emissions targets.

While offsetting remains the largest use case for carbon credits, they can also be used simply as a mitigation funding mechanism, without any express role in offsetting or compensating for emissions. This "mitigation contribution" approach is increasingly advocated for by some observers (Chagas et al. 2025b) but has seen limited uptake thus far (see the section on "Sorting out voluntary claims").

HOW ARE CARBON CREDITS GENERATED AND USED?

Although any party could in principle develop a project for the purpose of mitigating emissions and claim to meet the required criteria for offsetting, developing a robust market for offsets requires governance bodies and systems for certifying projects and issuing carbon credits. Today, a variety of independent organizations and government regulatory bodies, referred to as "crediting programs," oversee carbon credit certification and issuance. (For more information on these bodies, see Part 2). Adherence to quality criteria is assessed through the application of methodologies tailored to specific project types.

Although the details vary from program to program, basic elements of the "project cycle" for generating carbon credits include: (1) project conception, development, and submission to crediting program; (2) validation; (3) registration; (4) verification; (5) credit issuance; and (6) termination (which may occur prior to end of project life). Once issued, credits may be transferred among

accounts and retired in registry systems. When credits are retired, they are permanently removed from circulation, signifying that they have been used towards a mitigation claim and can no longer be traded or claimed by any other entity. Transactions of carbon credits typically occur outside registry systems under a variety of contract structures (including forward purchase agreements, bilateral trades, and spot market transactions via exchanges).

In compliance contexts, regulated entities purchase and retire credits to meet emissions caps and regulatory obligations. In the VCM, companies typically retire credits to offset their value chain emissions and demonstrate progress towards voluntary goals like net-zero or carbon neutrality.

CARBON CREDIT "QUALITY"

For carbon offsetting to work, each carbon credit must accurately represent one ton of CO_2e emissions avoided or removed. For this to be the case, credited mitigation outcomes must meet several criteria, including additionality, robust quantification, permanence, and exclusive claiming (terms defined below). Carbon credit "quality" is shorthand for the degree to which these criteria are achieved. Some types of projects have an easier time meeting these criteria. When carbon credits that fail to meet these criteria are used for offsetting, they undermine the integrity of emissions caps and reduce the efficient achievement of environmental goals compared to the scenario where the capped sources reduce their own emissions directly.

Additionality

To use carbon credits for offsetting, the project behind them must be **"**additional**."** This means the project would not happen without the extra money from selling carbon credits (Broekhoff et al. 2024). If a project is already profitable on its own, required by law, or just part of normal business practices, it likely would happen anyway—so it doesn't provide any extra climate benefit. In those cases, the emissions would be the same with or without the credits, meaning the project cannot legitimately offset greenhouse gases.

Robust quantification

The GHG mitigation generated by a project must be robustly quantified so that avoided emissions (or enhanced removals) are not overestimated. Overestimation can occur if a project's baseline emissions—the hypothetical emissions that would have occurred in the absence of the project—are estimated too high. Because avoided emissions are calculated as the difference between the baseline and the project's actual emissions, an inflated baseline can make a project appear to avoid more emissions than it truly does. This leads to the issuance of excess credits that do not correspond to real climate benefits. Overestimation can also result from failing to account for carbon leakage, where a project inadvertently leads to an increase in emissions elsewhere.

Permanence

Credits used for offsets must represent the permanent avoidance or removal of GHG emissions. Long-term global warming is driven primarily by cumulative CO_2 emissions (Allen et al. 2009; IPCC 2021). If a project temporarily stores carbon (e.g., a forestry project is later cut down)—and the release of carbon from that project is not compensated by further reductions or removals—it will have no net effect on cumulative emissions. It therefore will not have the same effect as a permanent emission reduction (e.g., a reduction in fossil fuel use) and is not an effective offset. There is, however, ongoing debate about what storage timeframes can be considered effectively permanent from a policy standpoint[2] and whether temporary mitigation can be valued for its contribution to other climate goals, like lowering peak warming (Matthews et al. 2023; Cullenward 2023).

Exclusive claims

Credits need to constitute exclusive claims to mitigation outcomes, therefore mitigation must not be double counted. There are three strains of double counting. Double issuance is when two or more credits are issued for the same ton of GHG mitigation (e.g., if two crediting programs issue credits to the same project). Double use is when multiple entities use the same credit towards their climate targets (e.g., if the same credit

is retired multiple times). Double claiming is when credits are issued for an emissions reduction another entity claims (e.g., if credits issued for a demand-side energy project also allow a local power plant to claim reduced emissions against a regulatory target) (Broekhoff et al. 2024).

Avoiding social and environmental harms

Mitigation projects can cause social and environmental harm. For example, hydroelectric projects can disrupt local ecosystems or dislocate communities, and poorly executed forestry projects can increase fire risk, introduce alien species, or abuse poorly defined land tenure. Avoiding these harms is not necessary for claiming a valid emission offset, but this criterion is frequently stipulated under the rationale that offsetting should not undermine other socially desirable objectives.

HISTORICAL DEVELOPMENT OF CARBON CREDIT MARKETS

1960–1997: Intellectual roots and early applications

The concept of carbon credits began with the birth of market-based environmental policy in the United States. In 1960, in his seminal "The Problem of Social Cost," Nobel laureate economist Robert Coase argued that pollution trading mechanisms could provide more efficient solutions to environmental externalities than flat taxes or hard limits on emitters (Coase 1960). In the late 1960s, Thomas Crocker (1966) and John Dales (1968) both proposed the idea of cap-and-trade systems, which involved setting a cap on pollution, issuing pollution allowances up to that cap, and then allowing polluters to freely trade allowances.

These ideas became U.S. policy in the 1970s. The Clean Air Act of 1970 set strict limits on local air pollutant emissions from power plants, enforceable with steep fines. Under a 1977 amendment, facilities could avoid these fines by paying another facility to cut even more of the same pollutant elsewhere (Gillenwater 2012). This opened the door for the broader application of tradable emissions rights.

In the 1980s, the U.S. successfully used emissions trading to accelerate the phase-out of leaded gasoline. The Environmental Protection Agency (EPA) issued lead credits to companies that produced gasoline with lead content below an allowed threshold. Credits could either be banked for future compliance use or sold to producers whose gasoline exceeded lead limits (Schmalensee and Stavins 2015). Follow-up studies showed that the program achieved lead reductions faster than projected and cost approximately 20% less than alternatives that did not incorporate emissions trading (Schmalensee and Stavins 2015). Building on the success of lead credits, the EPA in 1990 implemented a full-scale cap-and-trade system to reduce acid-rain-causing SO_2 emissions from coal plants (Schmalensee and Stavins 2015).

As the EPA introduced pollution trading, interest grew in the potential of nature-provided climate mitigation. In 1977, physicist Freeman Dyson was the first to propose that planting trees could offset the GHG emissions produced from burning fossil fuels (Dyson 1977). The 1980s saw a growing international focus on the prevention of tropical deforestation, driven primarily by concerns of biodiversity loss (FAO 1995). The first attempt to use "avoided deforestation" to offset carbon emissions came in 1987, when American power producer Applied Energy Services (AES) collaborated with the World Resources Institute to fund the world's first carbon offset project. AES spent $2 million to plant 52 million trees in Guatemala and offset 15 million tons of CO_2 emissions from a new coal fired power plant in Connecticut (Shabecoff 1988). In the following decade, interest from energy companies in offset investments increased, with companies such as BP and PacifiCorp engaging with NGOs like The Nature Conservancy to invest in forest conservation projects (TNC 2009). Rather than issuing tradable credits, early offsets were largely seen as one-off philanthropic endeavors. However, these projects helped set the stage for what would later become the VCM.

1997–2012: Emergence of international emissions trading

The United Nations Framework Convention on Climate Change's (UNFCCC's) Kyoto Protocol, adopted by 160

nations in 1997, was the first international agreement to introduce tradable carbon offset credits and the first to include binding GHG emissions reduction targets for all developed nations (Bassetti 2022). To assist nations in meeting their targets efficiently, the Protocol included three "Flexible Mechanisms:" Emissions Trading, Joint Implementation (JI), and the Clean Development Mechanism (CDM). Emissions Trading allowed countries that exceeded their targets to trade emissions reductions with other countries. JI allowed countries with emissions reductions targets under the Kyoto Protocol (Annex B countries) to cooperate on shared mitigation projects and issue Emission Reduction Units (ERUs) The CDM, meanwhile, allowed developed countries to purchase credits, called Certified Emission Reductions (CERs), from mitigation projects in developing countries. The CDM and JI created the world's first market for tradable project-based carbon credits, and the CDM developed many of the standards still employed in carbon markets today. The CDM introduced additionality requirements for offsets and required approved third-party verification. It also developed a list of allowable offset methodologies and quantification protocols for renewable energy, gas capture, and energy efficiency projects (UNFCCC, n.d.-a). Notably, the approved methodologies did not allow for avoided deforestation credits due to concerns about accurate emissions quantification and carbon leakage (Schlamadinger et al. 2007). This created a split between the newly formed compliance credit market and the nascent voluntary market focused on forestry projects.

The U.S. played a key role in pushing for the inclusion of a carbon market in the Kyoto Protocol (Hovi et al. 2010; Hunter and Powers 2013). Drawing on the success of the EPA's lead credits and SO_2 cap-and-trade program, the Clinton administration viewed the creation of a carbon market as crucial to reducing the cost of climate mitigation (Yellen 1998). Speaking to the House of Representatives, Janet Yellen, then chair of President Clinton's Council of Economic Advisors, said: "In taking action to reduce those emissions, economic analysis suggests that two elements are absolutely essential: The effort must be global, to address the global externality inherent in the nature of the problem. The effort must be flexible and market-based, to ensure that we achieve our objectives in the most efficient manner possible" (Yellen 1998).

However, despite its success in shaping the Kyoto Protocol and securing a flexible mechanism, the U.S. never became a party to the agreement. Prior to the UNFCCC meeting in Kyoto, the U.S. Senate passed the Byrd-Hagel Resolution 95-0, expressing disapproval of any agreement that did not include binding targets for developing countries. Because the Kyoto Protocol lacked targets for developing countries, President Clinton never submitted the treaty to the Senate for ratification (DOS 1998). In 2001, the Bush administration reinforced the U.S. position as a non-party, deprioritizing climate action and emphasizing uncertainty in the scientific consensus on climate change. Thus, the U.S. played an integral role in creating the world's first carbon market, but fell short of becoming a participant or introducing a national carbon emissions trading system (ETS).

Instead, the first country to establish a national ETS was the United Kingdom in 2002, followed shortly by the rest of the European Union in 2005 (Smith and Swierzbinski 2007). The EU ETS built on the market-based cap-and-trade approach pioneered by the U.S. and linked its compliance carbon market with CER and ERU markets through the Kyoto Protocol's Flexible Mechanisms. Large emitters in the EU were issued carbon allowances—largely for free—and required to surrender allowances equal to their carbon emissions at the end of each year. Companies could also surrender CERs or ERUs to comply with the EU ETS, and some companies engaged in arbitraging behavior between lower-priced CER/ERU credits and more expensive EU allowances (La Hoz Theuer et al. 2023; Patnaik 2023). The inclusion of offset credits in the ETS made the EU a key source of demand for Kyoto CERs.

As the compliance market took shape abroad, in the U.S., the VCM continued to grow while maintaining its focus on forest-based activities. Companies in the U.S. were not subject to compliance obligations, but many still sought to reduce their emissions and improve their public image in a growing movement towards "carbon neutrality." Consequently, in the late 1990s and early 2000s, an ecosystem of voluntary offset buyers, sellers, and verifiers slowly emerged. This period gave birth to the first independent carbon crediting programs. In 1996, the American Carbon Registry (ACR) was founded, making it the first independent registry

to track and issue offset credits (ACR 2023). In 2006, the Voluntary Gold Standard (GS) was established, bringing verification standards for energy and industrial projects from the CDM to the VCM. The Voluntary Carbon Standard (VCS) launched what would become the world's largest VCM registry in 2007, and in 2008, the Climate Action Reserve (CAR) inaugurated the largest voluntary program in North America (Carbon Offset Guide, n.d.). Meanwhile, companies like Microsoft and Disney published ambitious climate goals largely built around purchasing offsets (Gonzalez 2013; UNFCCC 2023a).

2012–2015: Decline of the Kyoto Protocol

By the end of 2012, global independent offset programs had issued over 180 million credits (World Bank 2025). However, the size of the VCM paled in comparison to the rapid growth of the Kyoto markets. Between 2005 and 2012, the UNFCCC issued over 1 billion CERs and 800 million ERUs (UNFCCC 2012, 2013). Over a billion of these credits were retired for compliance in the EU ETS (ICAP 2025). However, the credits issued by the Kyoto Protocol had serious issues. When assigning emissions limits, the Kyoto Protocol had set targets relative to a 1990 emissions baseline. For most countries, emissions had steadily grown between 1990 and 1997, making for meaningful targets. However, in former Soviet economies, emissions had declined dramatically following the dissolution of the Soviet Union in 1991. Therefore, baselines for Russia and Ukraine pegged to 1990 emissions were enormously inflated, enabling them to issue an oversupply of non-additional ERUs without compromising their targets (Kollmuss and Schneider 2015). Meanwhile, the CDM also faced its own challenges with additionality. Early on, the majority of CERs came from industrial gas destruction projects (UNEP 2013). By destroying highly potent GHGs, these projects could generate enormous volumes of credits at low costs. In fact, their credit output was so high, it raised concerns that facilities were intentionally increasing their greenhouse gas output to destroy more gas for credits (Schneider 2011).

By 2011, the EU had recognized the issues with Kyoto credits. Effective in 2013, the EU announced a range of restrictions on the use of offsets in its ETS, including a ban on the use of industrial gas credits and a cap on the total number of credits that would be accepted by the system (ICAP 2025). Simultaneously, international support for the Kyoto Protocol was unraveling following the end of the first commitment period in 2012. Canada withdrew from the protocol in 2011 to avoid penalties for missing its target, and Russia, Japan, and New Zealand announced that they would not adopt targets for the second commitment period (Rosen 2015). With declining demand and an oversupply of cheap, low-quality credits, the Kyoto markets collapsed by the end of 2012. The price of CERs fell from over $20/ton in 2008 to below $1/ton in 2012, so low that most new projects could not break even (The Economist 2012; UNFCCC 2012, 2023b). Issuance of international credits declined by 80% between 2012 and 2014, with registration of new projects nearly completely halting (World Bank 2025; UNFCCC 2012, 2023b).

In the wake of Kyoto's collapse, international climate negotiations turned their focus towards creating a successor treaty. Meanwhile, many national and regional governments continued to ramp up climate action. By the end of 2015, around 40 nations and 20 regions had begun to implement regional carbon pricing systems (Rydge 2015). Many of these fledging systems included governmental offset programs that issued credits specifically for use in domestic compliance markets (ICAP 2025). In the U.S., these included the Regional Greenhouse Gas Initiative which began regulating power plant emissions in 2009 and the California Cap-and-Trade program which launched in 2012 (and remains linked to a similar program in Québec, Canada). In parallel, VCM credit issuances continued to hold steady around 50 million per year even as CER issuances declined (World Bank 2025).

2015: The Paris Agreement

In 2015, the Paris Agreement was adopted by all 196 parties to the UNFCCC, setting a new course for the future of international climate action (UNFCCC, n.d.-d). Where Kyoto introduced binding emissions targets for developed countries, the Paris Agreement was built around flexible Nationally Determined Contributions (NDCs) which allowed all countries to set their own level of climate ambition. Paris also outlined the future of global

emissions trading, introducing Article 6 to replace Kyoto's Flexible Mechanisms.

Article 6 includes two separate frameworks for countries to trade carbon credits towards their NDCs: Article 6.2 enables decentralized emissions trading where individual countries approve their own crediting procedures. Article 6.4 creates a centralized crediting program called the Paris Agreement Crediting Mechanism (PACM) (UNFCCC, n.d.-b). The PACM provides a successor to the CDM and is overseen by a United Nations Supervisory Body which is responsible for operating a centralized registry and approving methodologies and quantification protocols. For credits from Article 6 to be counted towards a buyer country's NDC, they must be added back to the seller country's emissions ledger to prevent double counting, a process known as Corresponding Adjustments. Like Kyoto CERs, credits issued under Article 6 may also be available to companies for use in compliance and voluntary markets.

Since the Paris Agreement was signed, negotiations have been ongoing to flesh out Article 6, but the system is only now beginning to approach operationalization. The first (and only to-date) transfer of Article 6.2 credits—known as Internationally Transfered Mitigation Outcomes (ITMOs)—occurred in early 2024 between Switzerland and Thailand (Gupte 2024). In late 2024, the Article 6.4 rulebook was finalized, setting out requirements for mitigation projects to be issued credits (Dossi and Crook 2025). The first Article 6.4 credit issuance occurred in early 2026 (Jardine 2026). The rules for Article 6.4 embody many of the lessons learned in the wake of Kyoto's collapse. Article 6.4 allows for a broader range of project types than the CDM, including nature-based solutions, but projects are subject to stricter integrity safeguards. These safeguards (some of which remain controversial) include conservative, downwardly adjusted emissions baselines (to limit overestimation) and requirements for continuous monitoring of reversal risk (to ensure permanence) (Mulder 2025). Additionally, some existing CDM projects are eligible to transition to the PACM, provided they adopt Article 6.4 methodologies (Granziera et al. 2025).

The requirement of applying Corresponding Adjustments for Article 6 credits reflects the structure of the Paris Agreement in which all countries, not just developed nations, are expected to set ambitious climate targets. However, Article 6.4 also includes a separate class of credits called "mitigation contribution A6.4ERs" for which Corresponding Adjustments do not need to be applied. These mitigation contributions cannot be used towards NDCs but are still available for voluntary purchase (Granziera et al. 2025). It remains to be seen how the VCM will embrace the use of mitigation contribution A6.4ERs versus Correspondingly Adjusted Article 6.4 credits.

In the coming years, a significant source of demand for Correspondingly Adjusted credits under the Paris Agreement could be the International Civil Aviation Organization's (ICAO's) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Introduced in 2016, CORSIA requires airlines to purchase carbon credits to offset CO_2 emissions above 2019 levels. CORSIA's first implementation phase will last from 2024 to 2026 and will allow airlines to retire Correspondingly Adjusted credits issued by approved governmental and independent programs or the PACM (ICAO 2024a).

With the Paris Agreement trading system under construction since 2015, independent crediting programs have grown over the past decade to become the largest source of carbon credit supply (World Bank 2025). In this time, the global VCM has diversified significantly to include credits across a wide swath of project types. The past three decades of experience demonstrate the gains that have been made in operationalizing and advancing the use of carbon credits. However, the market remains in a state of transition, as standards organizations and buyers continue to assess credit quality and adjust their preferences.

Part 2: Overview of current carbon credit markets

Carbon credit markets today are diverse, with many international, regional, and domestic programs serving both regulatory and voluntary demand. Most recent activity has been in the global voluntary carbon market, while Paris-aligned compliance markets are expected to drive future growth. Despite this diversity, these markets face common challenges. On the supply side, there are ongoing concerns about the quality of carbon credits. On the demand side, there is uncertainty about how credits should be used in national and corporate decarbonization efforts. In response, various initiatives have emerged to address these issues.

SUPPLY SIDE

Carbon credits are issued by crediting programs (sometimes also referred to as "carbon standards" or "registries"). Crediting programs define the rules and criteria for how projects can produce carbon credits, evaluate projects according to their standards, and operate registry systems to track transfers and retirements of the credits they issue. There are three types of crediting programs, differentiated by the entities that administer them: UN, governmental, and independent.

UN crediting programs

UN-administered crediting programs include the Kyoto Protocol's CDM and Paris Agreement's Article 6.4 mechanism (or PACM). Rules for these crediting programs are determined through UNFCCC negotiations and implemented by UN Supervisory Bodies.

Governmental crediting programs

Governmental crediting programs are designed and operated by national or subnational governments and issue credits primarily for use in compliance systems (e.g., Australian Carbon Credit Units or Chinese Certified Emission Reductions). Typically, programs run by national or subnational governments issue credits only to projects within their geographic jurisdiction, although there are some exceptions (Japan's Joint Crediting Mechanism, for example, issues credits for projects implemented in foreign countries, which may ultimately be used by Japan under Article 6.2 of the Paris Agreement).

Independent crediting programs

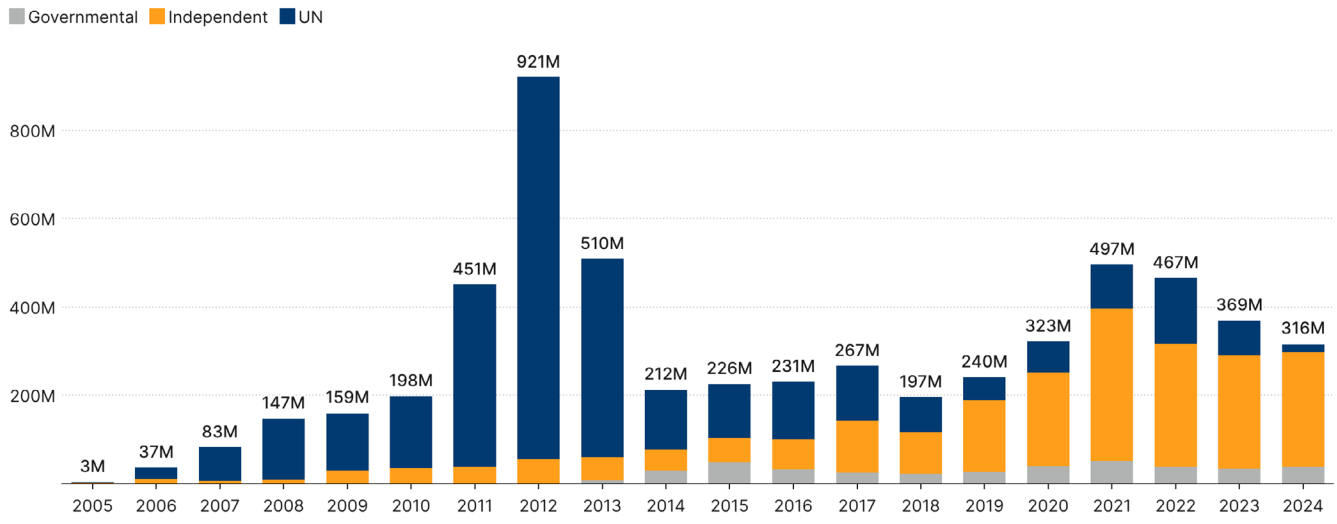
Independent crediting programs are operated by non-governmental organizations which set their own standards and issue credits to projects throughout the world. Some programs are global in scope, while others focus on specific geographies. The five largest independent crediting programs—Verra's Verified Carbon Standard (VCS), the American Carbon Registry (ACR), Climate Action Reserve (CAR), Architecture for REDD+ Transitions (ART)[3], and Gold Standard (GS)—account for 98% of independent credit issuances (SustainCERT 2024). While these programs primarily serve voluntary demand, the credits they issue are sometimes eligible for use in national regulatory programs and in the future could be authorized by governments for use in Article 6.2 trades.

Supply trends

Since the Kyoto Protocol was operationalized in 2005, over 5.9 billion carbon credits have been issued across all crediting programs (World Bank 2025).[4] Of these credits, nearly 2.5 billion originated from the Kyoto CDM (UNFCCC, n.d.-c). Over 2.2 billion credits have been issued by independent crediting programs, and close to 400 million have come from governmental mechanisms (World Bank 2025; Haya et al. 2025). As seen in Figure 2, credit issuances peaked in 2012, when over 850 million UN credits were issued in the final year of Kyoto's first compliance period (World Bank 2025). Following Kyoto's collapse, independent crediting programs have become the largest issuers in the market, reaching a peak of 345 million credits issued in 2021 (World Bank 2025). Since 2021, independent issuances have declined slightly to almost 260 million in 2024 (World Bank 2025).[5]

FIGURE 2

Annual Carbon Credit Issuance, 2005-2024 (Tons CO_2e)



Source: World Bank, Carbon Pricing Dashboard

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Generally, credits on the market are generated by two broad project types: avoided emissions and enhanced removals.

Avoided emissions projects prevent future emissions, for example by capturing methane gas from a landfill, replacing fossil fuels with renewable energy, or reducing demand-side energy consumption. A prominent category of avoided emissions is "reducing emissions from deforestation and forest degradation," referred to as REDD+. REDD+ projects entail implementing forest protections or improved management practices (usually in developing countries) to avoid emissions from future deforestation (UNFCCC, n.d.-e).

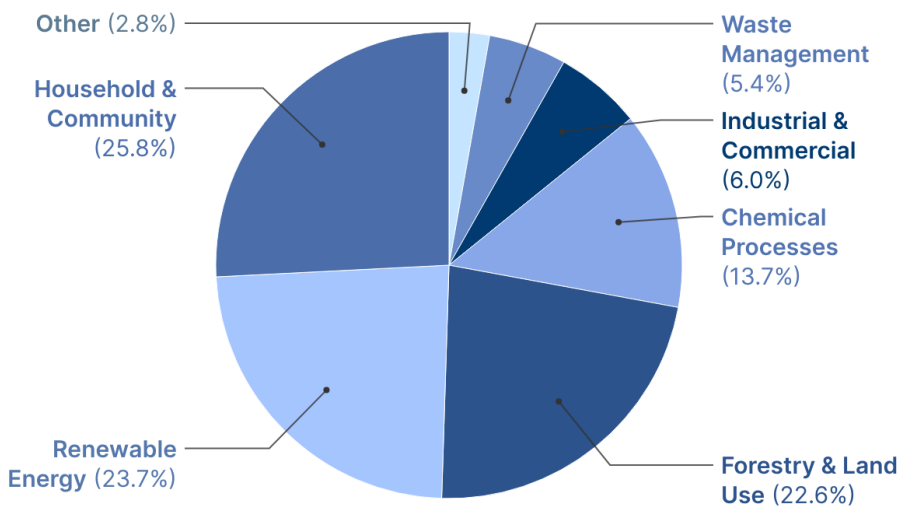
Enhanced removal projects take CO_2 out of the atmosphere and store it. Nature-based removals store CO_2 in biomass, either by planting trees or restoring ecosystems, and engineered removals, like direct air capture, store CO_2 in geologic reservoirs using artificial means.[6]

In 2025, 84% of the credits issued by the four largest independent crediting programs came from avoided emissions, 4% came from enhanced removals, and 12% came from projects that incorporated both (authors' calculation based on Haya et al. 2025). Nearly all credits issued for removals were for nature-based removals, with engineered removals accounting for only 0.05% of total credit issuance. Household and community projects, mostly focused on energy efficiency and clean cookstoves, constituted the largest market segment, accounting for 26% of credits issued. Renewable energy projects produced nearly 24% of credits, while forestry and land use projects, consisting of both project-based REDD+ and nature-based removals, supplied nearly 23%. As shown in Figure 3, chemical processes (like ozone-depleting gas destruction), industrial improvements, and waste management each also contributed significant shares (Haya et al. 2025).

Over time, the types of projects supplying credits have shifted. Under the CDM, the majority of credits were produced by renewable energy and industrial gas destruction projects. Since 2012, forestry and renewable energy projects have produced most of the credits issued by independent programs. However, in the past five years, issuance of credits from renewable energy projects has declined substantially, falling by over 70 million credits per year since 2021 (authors' calculation based on Haya et al. 2025). This likely reflects the weakening case for additionality as business-as-usual adoption of wind and solar becomes increasingly widespread. Issuance from household and community projects, such as clean cookstove distribution, has increased fourfold since 2021. A nascent segment of supply is engineered removals. In recent years, the mar-

FIGURE 3

Independent Credit Issuance by Project Scope, 2025



Source: Haya et al. 2025

Note: The Other category consists of 2.57% Agriculture, 0.16% Transportation, and 0.05% Carbon Capture and Storage. Contains credits issued by American Carbon Registry, Climate Action Reserve, Gold Standard, and Verra.

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ket for engineered removals has mostly consisted of forward purchases of credits that will be delivered in the future from yet-to-be-developed projects. However, in 2025, Verra issued 115,000 credits to a biochar project in India, marking the first large issuance of credits to an engineered removal project by a major independent registry (Haya et al. 2025).

Of the over 2.2 billion credits issued by independent programs since 2005, only 1.49 billion have been retired. This leaves a pool of over 700 million un-retired credits still available for use (Haya et al. 2025). Some of this surplus consists of credits that have been purchased by buyers and are likely to be retired in the future. However, a large portion likely consists of credits produced using outdated or discredited methodologies for which there are few potential buyers. The large supply of unretired credits is indicative of the ways in which carbon credit markets do not function like typical commodity markets. In theory, each credit should represent an identical ton of carbon avoided or removed from the atmosphere. However, in practice, the market has exhibited substantial differences in quality.

Carbon credit quality issues

Empirical evidence suggests that carbon credits have frequently failed to adequately meet core quality criteria, including additionality, robust quantification, permanence, and avoidance of social and environmental harms (Probst et al. 2024; Macintosh et al. 2025b; Romm et al. 2025). Many credits continue to be issued to projects that are likely non-additional or significantly overestimate their emissions. These problems owe to weak standards, flawed program design, and perverse incentives, which a growing number of independent bodies, rating agencies, and government-backed initiatives are seeking to address.

Analyses of North American forestry projects and renewable energy projects in multiple countries suggest that prevailing standards have failed to exclude many projects with few or no additional benefits (Sanders-DeMott et al. 2025; Stapp et al. 2023; Badgley et al. 2022; Calel et al. 2021; Cames, Harthan, Füssler, et al. 2016; Chan 2015). Similarly, studies of clean cookstove projects and projects that reduce deforestation suggest

that they frequently exaggerate baseline emissions, resulting in the over-issuance of credits (Gill-Wiehl et al. 2024; West et al. 2023). A recent survey found that fewer than 16% of credits issued to forestry, cookstove, wind power, and industrial mitigation projects over the past 20 years—representing around 20% of all carbon credits ever issued—are associated with truly additional mitigation (Probst et al. 2024).

Low-quality projects that claim to avoid emissions have been scrutinized recently, contributing to perceptions that avoided emissions projects are especially prone to quality concerns (Padin-Dujon 2025). However, similar issues have been identified for many removal activities, including afforestation and soil management projects, which may be equally susceptible to over-crediting (Macintosh et al. 2024; Barbato and Strong 2023).

Quality concerns, especially for removals, extend to questions about permanence. Multiple forestry projects registered in California's offset program, for example, have suffered significant reversal events when the trees burned in wildfires. While these losses were anticipated by creating a "buffer pool" of credits, one study suggests that this pool is too small to cover wildfire risks over the long run (Badgley et al. 2022). Separate studies suggest buffer pools in other programs may also be insufficient, leading to concerns that, across the market, permanence is not being effectively managed (Anderegg et al. 2025). Furthermore, crediting programs have adopted a variety of sometimes inconsistent approaches to managing permanence, including different requirements for the length of time over which reversal events must be monitored and compensated (ranging, for example, between 5 and 100 years after a project starts or after a credit is issued) (FAO 2024; Michaelowa et al. 2025).

Finally, some quality concerns extend beyond emissions integrity and into social and environmental harms. For example, many land-based mitigation activities have been criticized for failing to benefit local communities, and in some cases displacing indigenous residents (Enríquez-de-Salamanca 2024; Snyder 2023).

Worries about the quality of credits issued under independent crediting programs have been raised since their inception (Gillenwater et al. 2007; Kollmuss and Bowell 2007). Early studies of the CDM (then the world's largest carbon crediting program) also raised questions about credit quality (Schneider 2007). Retrospective studies in the mid-2010s identified significant issues with additionality (Spalding-Fecher et al. 2012), with one study suggesting that up to 73% of carbon credits issued under the CDM may not have represented valid mitigation (Cames, Harthan, Füssler, et al. 2016). Media reports from the time describe deceitful claims by project developers as "standard practice" (McCully 2008), and in multiple instances third-party verifiers were suspended from the CDM for approving projects that they suspected to be non-additional (Szabo 2010). Examples of non-additional CDM projects that were issued credits include coal-fired power plants in India and hydroelectric dams in China constructed by state-owned power companies (Haya and Parekh 2011; McCully 2008).

Why quality problems persist

Persistent quality issues—over time and across different crediting programs—raise questions about the effectiveness of carbon credit markets as a tool for mitigating climate change, suggesting that these markets face systematic challenges. Some of these challenges are methodological in nature, including risks posed by adverse selection and perverse incentives. Others arise from potential conflicts of interest in how crediting programs operate. These challenges can be addressed through robust methodologies and effective program design and governance. A more difficult challenge is that crediting programs are almost always designed to serve multiple objectives, some of which can entail tradeoffs with respect to credit quality. Designing effective markets and allaying quality concerns requires an understanding of these tradeoffs.

Adverse selection

To determine a project's additionality and quantify its mitigation impact, crediting programs compare it to a baseline scenario—i.e., a scenario characterizing the activities, and associated emissions, that would have occurred without the incentive to sell carbon credits. Standard methods for determining baselines are prescribed by methodologies tailored to each project

type. However, even stringent methods are not infallible, which makes them prone to adverse selection. Adverse selection can occur because credit sales will be especially appealing for projects which are either non-additional (i.e., they do not require carbon credits to be financially viable) or which have true baselines that are lower (less emitting) than crediting programs' estimates (Millard-Ball 2013; Bushnell 2011; Montero 1999). These projects need to do very little to claim emissions improvements and therefore will disproportionately opt into selling credits if they are not effectively screened out by program rules.

A recent example of adverse selection is the issuance of improved forest management credits for use in California's cap-and-trade system. Stapp et al. (2023) identified that forests enrolled into the carbon crediting program tended to have historically lower rates of harvest than forests that were used to set the baseline. Therefore, projects could generate credits against the baseline without needing to make any changes to how their forests were managed. A similar study by Coffield et al. (2022) found no evidence that forests enrolled in the program reduced their harvesting at all compared to past harvesting rates. In this case, rather than improving forest management, the crediting program simply selected forests that were already being managed in a less extractive way.

Adverse selection is a major problem in carbon credit markets. Low-quality credits—those that are non-additional or overestimated—tend to be cheapest because they cost little to produce (Trexler et al. 2006). If too many of these credits enter the market, they can drive prices down so much that high-quality, truly additional projects are no longer viable, potentially leading to market failure. This problem is worsened because buyers often cannot judge credit quality themselves and must rely on third-party assessments. As a result, they discount what they are willing to pay to account for the risk of bad credits (Akerlof 1970). This pushes out high-quality sellers while low-quality ones remain. Over time, if credits that look the same no longer represent the same emissions outcomes, the market stops functioning properly.

Perverse incentives

Carbon credit programs turn unregulated GHG emissions reductions into a source of revenue, encouraging cuts that might not otherwise happen. But these incentives can lead to unintended behavior. Developers may exaggerate baseline emissions or overstate reductions to earn more credits. Some may delay reducing emissions now in hopes of earning credits later. In extreme cases, firms may even create new emissions just to get paid for reducing them. There is evidence of this happening. One study found that refrigerant factories increased production of HFC-23—a potent greenhouse gas—when they could earn credits for destroying it under the Kyoto CDM (Schneider 2011). Another found that adipic acid production shifted to unregulated plants so they could earn credits for cutting emissions from byproducts (Schneider et al. 2010).

Conflicts of interest

Nearly all carbon crediting programs require projects to undergo third party auditing. However, in most cases, third party reviews are paid for not by credit buyers or regulators but by project developers, creating a conflict of interest where auditors may treat project developers favorably to secure future business (Giles and Coglianese 2025). A similar issue arises with methodology development. Under many crediting programs, methodologies are typically developed and submitted by project proponents. This is a useful way to outsource the cost of developing a portfolio of methodologies covering multiple types of projects, but it can mean that methodologies will be favorable to project developers' interests unless program staff or regulators effectively push back against lenient methods and assumptions (Cabiyo and Field 2025).

Tradeoffs involved in solving for multiple objectives

As mentioned earlier, carbon crediting programs are designed with multiple objectives in mind. While their primary purpose is to facilitate the mitigation of climate change, secondary objectives include channeling investment into certain types of high-value mitigation

activities, cost containment (e.g., lowering the cost of compliance for regulated emitters in cap-and-trade systems), and supporting various constituencies that engage with carbon markets. However, satisfying secondary objectives can present tradeoffs with respect to climate impact and credit quality.

When it comes to core quality criteria, for example, crediting programs can set a high bar by adopting stringent additionality tests, conservative baseline methodologies, and rigorous permanence requirements. Doing so will tend to exclude lower quality projects from eligibility but can also inadvertently exclude some high quality projects (Trexler et al. 2006).

For some projects, meeting stringent quality criteria is harder than for others—especially those often favored by policymakers or voluntary buyers. For example, nature-based climate solutions can deliver social and environmental co-benefits, but they have more difficulty proving additionality, measuring impacts, and ensuring long-term results (Broekhoff and Zyla 2008). Avoided deforestation projects are a key example. They require estimating what deforestation would have been without the project, but these baselines are highly uncertain because deforestation varies by location and economic conditions. As a result, crediting programs must choose between strict baselines that exclude many worthwhile projects or more lenient ones that allow broader participation but increase the risk of over-crediting.

Similar dynamics arise with additionality assessments. For some project types, such as engineered removals, there are extremely few incentives for project development other than carbon credit revenue, making the underlying pool of non-additional projects very small. However, other activities, like renewable energy development, have widespread business-as-usual deployment and therefore have large pools of non-additional projects. While supporting renewable energy may be desirable from a policy perspective—and there are certainly projects in need of carbon revenue—in practice it has proven difficult to effectively screen out the large number of non-additional projects.

In short, crediting programs can implement rigorous tests with strict requirements to maximize quality, but they do so at the risk of limiting the supply of carbon credits, reducing the potential for cost containment, and excluding some valuable projects. In practice, many crediting programs have opted to employ more lenient standards because they are trying to solve for multiple objectives: practicality and feasibility, satisfying political constituencies, and channeling funding to preferred mitigation activities.

Raising the bar: New oversight bodies and rating agencies

Several initiatives have been launched since 2020 to address quality concerns, establishing novel institutions and frameworks for bolstering supply-side integrity. Many of these initiatives have focused on the VCM but have the potential to influence compliance markets.

In the lead-up to the COP26 climate conference in Glasgow, the Institute of International Finance, an association of global banks, launched the Taskforce on Scaling Voluntary Carbon Markets (TSVCM).[7] The TSVCM was high-profile initiative (backed by Mark Carney, then the UN Special Envoy for Climate Action and Finance) designed to scale voluntary carbon markets by addressing gaps in market governance and infrastructure and, importantly, boosting market confidence through the development of a new "high integrity" labelling system. To fulfill the latter objective, the TSVCM disbanded to form the Integrity Council for the Voluntary Carbon Market (ICVCM) in 2022.

In 2023, the ICVCM released a set of "Core Carbon Principles" (CCPs) for high quality carbon credits (ICVCM 2023). It has since assessed multiple independent crediting programs and their standards against these CCPs. The ICVCM has also identified improvements needed in some standards, and carbon crediting programs have responded by revising their methodologies accordingly (Verra 2025a).

The ICVCM's efforts have been aided by other independent assessment efforts, including the Carbon Credit Quality Initiative, which assessed the quality of multiple highly used methodologies in the VCM (most of which were rated poorly).[8] In parallel, ICAO has assessed and approved multiple independent carbon crediting

programs for the purpose of generating eligible offset credits for CORSIA, the carbon offsetting scheme for international aviation (ICAO 2022). Under this process, ICAO excluded some methodologies used by these programs from eligibility, based on both policy and quality considerations. The ICVCM has adopted CORSIA requirements as a minimum benchmark for granting a CCP label.

One challenge with these initiatives is their focus on methodologies. While improving methodologies and enhancing their stringency is essential for improving overall market quality, such efforts can overlook considerable variations in the quality of individual projects registered under a single methodology. Non-additional projects may still be mistakenly registered, for example, under methodologies with stringent additionality tests. Conversely, studies have shown that not all projects registered under lenient methodologies suffer from over-crediting (West et al. 2020).

Because of this, there has been growing demand for quality assessments of individual projects. Since 2021, for-profit carbon credit rating services, like BeZero, Sylvera, and MSCI, have arisen to fill this need, providing project-level ratings for hundreds of projects. While different service providers have themselves adopted different proprietary (and at times inconsistent) rating schemes, they have generally pointed to common quality issues for individual projects and project types (Wawrzynowicz et al. 2023).

Collectively, there is evidence that these various initiatives and rating services have had a positive effect, shifting VCM demand towards higher quality credits (Berends et al. 2025; Loffler and Joshi 2025). CCP-labeled credits, for example, demand a price premium, indicating a buyer preference for quality (Forest Trends' Ecosystem Marketplace 2025). Buyers have also started to show stronger demand for recently issued credits (which may tend to be of higher quality) and credits issued for projects certified to meet sustainable development goals (Forest Trends' Ecosystem Marketplace 2025).

Within compliance markets, the influence of these initiatives is still nascent. However, they may be useful for countries engaged in cooperative approaches under Article 6.2. For example, host countries could use assessment frameworks like the ICVCM's to inform their decisions about whether to authorize carbon credits as ITMOs (ICVCM 2024; Broekhoff and Spalding-Fecher 2021).

DEMAND SIDE

Demand for carbon credits consists of voluntary demand for climate commitments (like net zero pledges) and compliance demand to fulfill legal commitments or regulatory obligations. Voluntary buyers tend to use credits issued by independent crediting mechanisms, while most compliance systems require credits from UN- or government-administered programs. Some compliance systems, however, also accept certain types of independently issued credits.

Voluntary demand

Since the end of Kyoto's first compliance period in 2012, the VCM has grown to account for the largest share of carbon credit demand (Wetterberg et al. 2025). The signing of the Paris Agreement in 2016 ushered forth a wave of corporate climate commitments, many of which prominently featured the use of carbon credits. In just four years between 2017 and 2020, spending in the VCM increased steadily, growing from $136 million to $534 million (Forest Trends' Ecosystem Marketplace 2025). During this same period, annual transaction volume in the VCM increased from under 50 million tons (Mt) CO_2e in 2017 to over 200 Mt in 2020 (Forest Trends' Ecosystem Marketplace 2025). Between 2020 and 2021, VCM transaction volume more than doubled again, reaching over 500 Mt (Forest Trends' Ecosystem Marketplace 2025). The growth of the VCM in 2021 was driven by a confluence of events leading to an influx of new market participants. That year the Science Based Targets Initiative (SBTi) launched its corporate decarbonization framework, leading over 750 companies to adopt more ambitious climate commitments (Harris 2022). At the same time, the ICVCM was founded, increasing already widespread optimism in the expanding role of the VCM in climate action (Harris 2022). By 2021, the VCM had come to account for up to 90% of total carbon credit demand (Wetterberg et al. 2025).

After peaking in 2021, VCM market activity declined significantly. In 2024, only 84 Mt of credits were exchanged on the VCM, representing a nearly 85% decrease over the past four years (Forest Trends' Ecosystem Marketplace 2025). Much of this decline has come because of increased scrutiny on the VCM brought on by highly publicized reports of widespread overestimation and additionality concerns (Greenfield 2023; Forest Trends' Ecosystem Marketplace 2024). In 2021, forestry and renewable energy credits were the two most in-demand categories, both of which suffered from especially severe integrity issues (West et al. 2020; Calel et al. 2021; Forest Trends' Ecosystem Marketplace 2022). Between 2021 and 2022, demand for forestry credits dropped 40% (Carew 2024). The extensive media coverage given to the issues with carbon credits created a reputational risk for buyers, most of whom themselves faced challenges distinguishing good credits from bad. A 2023 survey by Bain and Company found that 55% of potential carbon credit buyers identified lack of transparency and inconsistent quality standards as key barriers to participation in the VCM (World Economic Forum 2023). Meanwhile, 40% of companies believed that engaging with the VCM presented a reputational risk (World Economic Forum 2023).

In addition to reputational damage, many potential participants likely avoided the VCM due to legal risk. The early 2020s saw an uptick in class action lawsuits against companies for making false environmental statements (Tarantino et al. 2025). Many of these lawsuits specifically focused on the use of carbon credits in carbon neutrality claims. For example, a 2023 suit against Delta Airlines alleged that the company's use of low-quality credits made its carbon neutrality claim false or misleading (Berrin v. Delta Airlines, Inc. 2023). Since 2022, Delta has ceased its voluntary carbon credit purchases (Delta Airlines 2023).

Macroeconomic headwinds may also have contributed to the slowdown in the VCM. In 2020 and 2021, generous fiscal stimulus and low interest rates in the U.S. drove corporate profit margins to the highest level in a decade (Palazzo 2023). As the global economy cooled in 2022, corporate budgets tightened. In a 2023 survey of nearly 1,500 executives by Google, about 45% of respondents reported that the current economic climate was "regressing sustainability efforts" (Keeble 2023).

Despite declining credit purchases in recent years, there is reason to believe that strong underlying demand in the VCM still exists. One signal is that VCM credit retirements have largely remained steady at over 180 Mt per year since 2021 (Forest Trends' Ecosystem Marketplace 2025), indicating that even as companies scale back their purchases, they continue to use their existing pools of credits to offset their emissions. Another promising signal is growing demand for high-integrity credits. Substantial price premiums have emerged for credits with reliable third-party certification, reflecting buyers' increasing desire for quality assurance (Calyx Global and Clear Blue Markets 2026). In 2024, when the first wave of ICVCM CCP-approved credits were issued for landfill gas destruction, the market saw a 300% increase in demand for waste disposal credits (Forest Trends' Ecosystem Marketplace 2025).

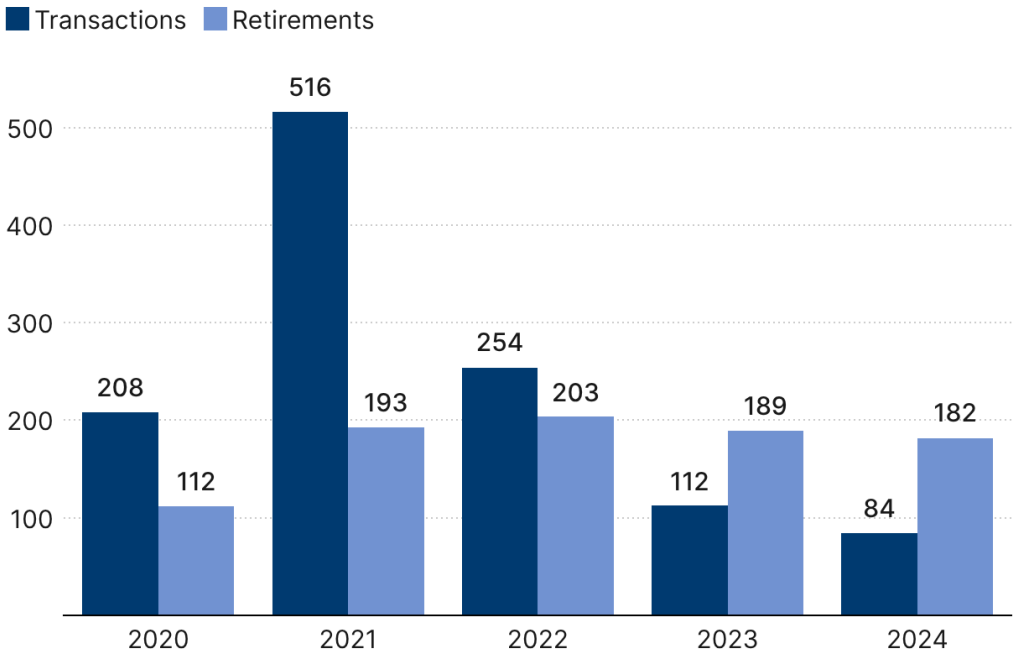
As the pool of high-quality credits grows and integrity initiatives provide more reliable information to buyers, the VCM may see a recovery of transaction volumes. However, uncertainty in the global economy remains an issue, and the stance of the current U.S. administration presents an additional challenge for companies engaged in climate action. In 2025, major firms doing business in the U.S. have stepped away from environmental, social, and governance (ESG) initiatives and many have gone quiet about—but not eliminated—their climate commitments (Rives 2025; The Economist 2025). As a consequence, the VCM remains in a delicate place. The integrity and transparency of the market is improving, but external factors may continue to constrict demand.

Compliance demand

Within compliance markets, most carbon credit demand is currently driven by carbon pricing policies, including national and regional ETSs. The most common form of ETS is the cap-and-trade model.[9] In a cap-and-trade system, the government sets an emissions cap and then issues emissions allowances equal to the cap. Allowances are distributed to firms through auctions, free allocations, or a combination. At the end of a compliance period, regulated firms must surrender allowances equal to their carbon emissions or face monetary penalties. In some ETSs, regulated entities can submit carbon credits in place of or in addition to emissions allowances to help fulfill their compliance obligations.

FIGURE 4

Annual Volume of Voluntary Credit Transactions and Retirements, 2020-2024 (Million Tons CO_2e)



Source: Forest Trends' Ecosystem Marketplace 2025

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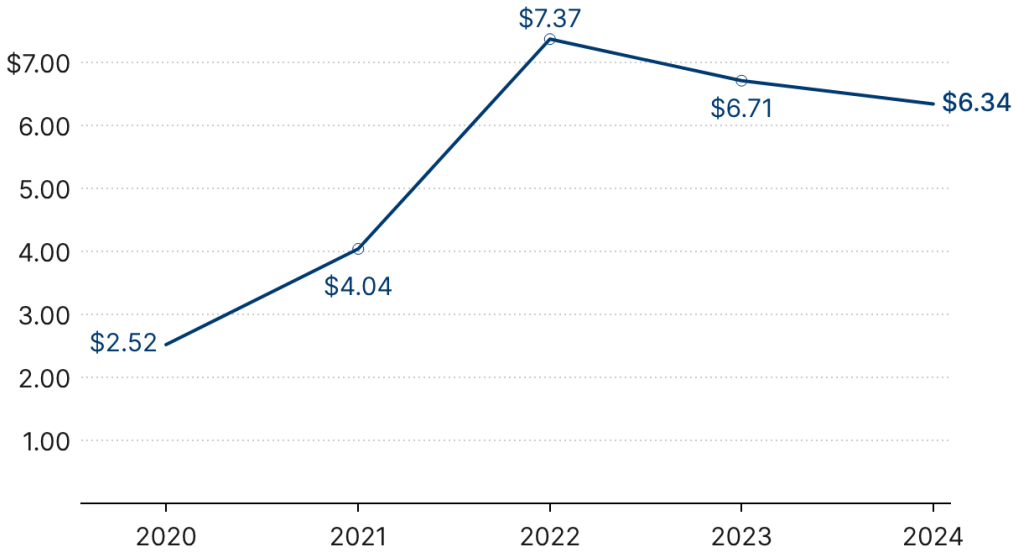
Average VCM Credit Price, 2020-2024



Source: Forest Trends' Ecosystem Marketplace, 2025

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ETS operators incorporate carbon credits into their systems for several reasons, which have already been discussed—namely, to channel investment to specific sectors, contain costs for ETS-covered firms, and support important political constituencies. As of this writing, out of the 38 ETSs in force globally, 24 allow for the use of carbon credits as a compliance option (ICAP 2025).

Within any given ETS, carbon credit demand is determined by the permitted use of credits and the scarcity of credits relative to emissions allowances. Most ETSs impose supplementarity limits, allowing only a certain percentage of each regulated source's compliance obligations to be met with carbon credits. Of the 24 ETSs that incorporate carbon credits, only seven—in Australia, Tokyo, Saitama, Kazakhstan, Indonesia, Canada, and the province of Alberta—allow credits to be used for more than 70% of compliance obligations (ICAP 2025). Of the remaining 17 systems that allow carbon credits, nearly all allow them only for a small portion of compliance obligations, usually less than 15% (ICAP 2025). In all systems, except South Korea's ETS, carbon credits must be sourced domestically from a directly linked governmental crediting program (Wetterberg et al. 2025).

As of 2024, the ETS with the greatest carbon credit demand is California and Québec's linked cap-and-trade system. In the compliance period from 2021 to 2023, covered entities in California and Québec surrendered 39.8 Mt of carbon credits (ICAP 2025). Other major sources of ETS carbon credit demand are South Korea's ETS, which saw 7.6 Mt of credit retirements in 2022 (ICAP 2025), Australia's ETS which saw 7.1 Mt of retirements from 2023 to 2024 (CER 2025), and China's ETS which saw 3.72 Mt of retirements from 2021 to 2022 (MEE 2024). Table 1 contains more information on carbon credit use in key ETSs.

Generally, carbon credits will be purchased in compliance systems only when their price is less than or equal to the price of allowances. For example, in California and Québec's linked cap-and-trade system, a stricter emissions cap drives higher allowance prices, making

TABLE 1

Carbon Credit Demand in Selected ETSs

ETS	Max carbon credit usage	Actual carbon credit usage*	Carbon credit retirements	Carbon credit pricing ($/ton)**	Allowance pricing ($/ton)**
California	4%	3.1% (CARB 2024)	26.2 Mt (2021-2023) (CARB 2024)	$20.9	$29
Québec***	8%	7.73% (MELCCFP 2024)	13.6 Mt (2021-2023) (MELCCFP 2024)	$20.9	$29
China	5%	0.037% (MEE 2024)	3.72 Mt (2021-2022) (MEE 2024)	$12.3-$14.8 (Sengupta 2025)	$12
Australia	100%	83.5% (CER 2025)	7.1 Mt (2023-2024) (CER 2025)	$19.8-$25.9	$22
Korea	5%	1.29% (ICAP 2025)	7.6 Mt (2022) (ICAP 2025)	$6.2-$17.1	$6
Kazakhstan	100%	0% (AIFC 2025)	0 Mt (AIFC 2025)	N/A	$1

SOURCES: Max carbon credit usage (ICAP 2025); carbon credit and allowance pricing (World Bank 2025).
*During period when carbon credit retirements are shown; **Approximate allowance pricing shown as of August 2025; ***California and Québec share compliance instruments.

carbon credits significantly less expensive and therefore used at nearly the maximum allowed amount. On the flipside, in China and South Korea's ETSs, where emissions caps are less strict, carbon credits trade at equal or higher prices than allowances and consequently see a small fraction of their possible use.

Carbon credit supply restrictions also impact the use of offsets across different ETSs. The rules and regulation of governmental crediting programs determine the scarcity of credit supply. Crediting programs with more lenient processes for approving projects tend to generate more credits, while programs with stricter requirements tend to approve fewer credits. For example, in Oregon's ETS, "Climate Community Investment" credits can only be issued by a select group of approved nonprofits and have a set price of $129 (ICAP 2025). Even though Oregon allows the credits to be surrendered for up to 15% of compliance obligations, it is likely that the actual quantity of credits produced and surrendered will be far lower owing to their high price (ICAP 2025). [10]

The EU ETS, the first compliance system to incorporate carbon credits, illustrates how the relative scarcity of credits and allowances can shape demand. In Phase I, from 2005 to 2007, the EU ETS allowed businesses to surrender Kyoto CER credits for up to 100% of their compliance obligations (Directive 2004/101/EC 2004). However, not a single CER was surrendered in Phase I because the emissions cap was set too high, and nearly all businesses were issued 100% free emissions allowances (La Hoz Theuer et al. 2023). Because the supply of allowances ended up exceeding total emissions, the price of allowances fell to zero towards the end of Phase I, and demand for carbon credits was rendered non-existent (European Commission, n.d.).

In Phase II, from 2008 to 2012, the EU ETS emissions cap was lowered, and issuances of free allowances were reduced, pushing up the price of allowances (European Commission, n.d.). Simultaneously, the supply of Kyoto CERs and ERUs also increased over 7-fold, driven mostly by non-additional renewable energy and industrial gas destruction projects in Asia (World Bank 2025; UNEP 2013; Cames, Harthan, Fussler, et al. 2016). At the beginning of Phase II, Kyoto CERs and EU allowances traded at similar prices. By the end of 2012, the price of an EU allowance was around €5/ton while the price of a CER was less than €0.5/ton (Patnaik 2023; Kainou 2022). This allowed firms to cheaply substitute carbon credits for allowances and save excess allowances for future use. In addition, some firms that used carbon credits for compliance also sold off EU allowances, exploiting the price difference between credits and allowances and capturing surplus rents as a result (Patnaik 2023). In total, EU businesses surrendered 1.058 gigatons of mostly non-additional Kyoto credits to meet their compliance obligations in Phase II (ICAP 2025).

The early phases of the EU ETS demonstrated the challenges of incorporating carbon credit use into ETSs. In Phase I, an inflated emissions cap rendered carbon credits meaningless. In Phase II, oversupply of low-quality credits risked undermining the integrity of the emissions cap, enabled firms to reap arbitrage gains on the price differential between EU allowances and Kyoto credits, and allowed firms to save allowances for future compliance periods (Patnaik 2023). Following 2012, the EU ETS implemented stricter restrictions on carbon credit use. In Phase III, an EU-wide supplementarity limit was applied, capping total carbon credit use at just over 500 Mt (ICAP 2025). The EU also implemented additional qualitative limits, allowing only credits from projects in least developed countries and banning the use of industrial gas credits (ICAP 2025). After 2020, with the Kyoto Protocol largely dormant, the EU ETS paused its use of carbon credits altogether.

The EU ETS experience influenced the design of subsequent compliance systems and demonstrated the necessity of implementing strict quantitative and qualitative limits governing the use of carbon credits. Instead of relying on Kyoto's Flexible Mechanisms, most major ETSs implemented after 2012 (including California's, Australia's, and Korea's) were linked with their own governmental crediting mechanisms. By developing their own mechanisms, governments could tailor crediting programs to achieve specific policy objectives and exercise tighter control over supply. However, the proliferation of government-administered programs created a highly fragmented ecosystem of compliance demand.

In today's market, compliance demand is primarily driven by national ETSs. In the future, international agreements are likely to play an expanding role. Countries will soon be able to buy Article 6.4 credits to help meet their NDCs, and many countries are already beginning to set up agreements to purchase ITMOs. By the end of 2023, 67 countries had signed Memorandums of Understanding or bilateral agreements related Article 6.2 ITMO transfers (Wetterberg et al. 2025). As the PACM reaches operationalization, countries may also look to once again reintegrate UN-issued credits into their domestic ETSs (Fursman et al. 2025).

Alongside the Paris Agreement NDCs, CORSIA—the carbon offsetting scheme for aviation—could be another major source of international compliance demand. CORSIA's first compliance phase, which ends in 2026, includes voluntary participation by 129 countries and is expected to generate 100-150 Mt of credit demand (ICAO 2024b; Legrady 2025).[11] Unlike governmental ETSs and Article 6, which are linked to their own crediting programs, CORSIA accepts credits from the six largest independent crediting programs. However, unlike the independent credits used in the VCM, CORSIA Eligible Emissions Units must have Corresponding Adjustments applied (ICAO 2024a). This means that airlines purchasing credits for CORSIA compliance may only draw from a subset of credits available on independent registries. Currently, only 15.8 Mt of CORSIA eligible credits have been produced, all from jurisdictional REDD+ projects in Guyana (Sylvera 2025). With credit retirements for the first compliance period due in 2028, it remains to be seen if credit supply will grow sufficiently to match projected demand (ICAO 2025).

Demand-side challenges: The potential for "mitigation deterrence"

Because the effect of GHG emissions is global, it does not matter in principle whether an emissions reduction target is achieved directly at certain sources or through a combination of direct reductions and carbon credits. In practice, however, this logic does not always hold, especially when offsets are used to justify added investment in high-carbon infrastructure or when they create disincentives for regulatory action. The potential of carbon credit use to distract from higher-value mitigation efforts is often referred to as "mitigation deterrence."

For example, regulatory targets for reducing GHG emissions are often set with the objective of driving systemic changes needed to decarbonize certain facilities, systems, or sectors. When emitters can meet reduction obligations by offsetting, however, they may delay direct investments in low-carbon technologies at their own facilities or make investments in high-carbon equipment or infrastructure. At an international level, for example, concerns have been raised about whether the EU's use of international carbon credits could detract from domestic mitigation efforts needed to align the EU's economy with Paris Agreement targets (De Grandpré and Senne 2026).

Regulatory programs have typically addressed the risk of mitigation deterrence by setting supplementarity limits capping the percentage of compliance obligations that can be met with carbon credits. The problem is that most supplementarity limits have in practice not been very stringent, because even a small percentage of allowed carbon credit usage can translate into a large percentage of total mitigation achieved. For example, if an emissions cap is set 10% below business-as-usual emissions (the emissions that would have occurred without the cap), then allowing carbon credits for up to 8% of compliance obligations could translate to 80% of all avoided emissions.[12] Precisely this scenario was projected at the outset of California's cap-and-trade program, where according to one analysis, the program's initial 8% limit on carbon credit usage could have amounted to 85% of all reductions achieved between 2013 and 2020 (Mulkern 2011).

Another form of mitigation deterrence can arise if the sellers of carbon credits resist policies—such as carbon taxes or regulation—that would compel mitigation and therefore cut off their revenue streams (because their actions would no longer be additional). This is especially counterproductive where regulation would be more comprehensive and effective, e.g., by driving mitigation at all firms in a targeted sector, not just those opting into a carbon crediting program. In a similar vein, at an international level, countries could be discouraged

from adopting more ambitious NDCs if they believe doing so would make it harder to attract carbon finance under Article 6 (Warnecke et al. 2018; Fearnehough et al. 2020). That said, there is little empirical evidence on the degree to which carbon crediting programs have contributed to these dynamics.

Concerns about mitigation deterrence extend to the VCM. For example, many companies with net zero emissions targets, which are among the most active purchasers of carbon offsets (Gabbatiss and Pearson 2023; Trencher et al. 2023; Ferris 2024), are vague about whether they plan to reduce emissions directly or offset them (Day et al. 2023, 2022; Hale et al. 2022). According to a 2021 survey, nearly nine in 10 companies viewed the use of offsets as an important part of achieving net zero strategies, including 56% that viewed use of carbon offsets as having "the highest potential for my company in the long-term" (IETA 2021, 15). However, consumers can be misled if companies imply they are reducing their own emissions but instead are failing to make investments needed to decarbonize their own operations and value chains. This has led to a growing consensus that companies should follow a "mitigation hierarchy," under which credits are only used to net out hard-to-abate emissions or provide additional contributions to global mitigation.

Net Zero commitments and the "mitigation hierarchy"

Since 2020, multiple initiatives have formed to encourage—and set guidelines for—the adoption of net zero emissions commitments by companies, financial institutions, and other "non-state" actors (Broekhoff and Verkuijl 2024; Hale et al. 2022). While details differ across these initiatives, they all align on the need to follow a mitigation hierarchy: actors must first reduce their value-chain or territorial emissions, typically in line with "science-based" targets, and only use carbon credits to support removals needed to net out hard-to-abate emissions or provide additional contributions to global mitigation. For example:

- The UN Race to Zero campaign suggests that actors can achieve net zero if they reduce their attributable emissions in line with global pathways that limit global warming to 1.5ºC and fully offset any remaining emissions with GHG removals. As a "leadership practice" actors may use high-quality carbon credits to support additional mitigation—such as by protecting nature, restoring peatlands, or ending deforestation—but such use may not substitute for reductions in attributable emissions (Race to Zero 2022; Race to Zero Expert Peer Review Group 2022).
- The International Organization for Standardization's 2022 Net Zero Guidelines recognize the use of carbon credits to support "additional voluntary action" but not to claim achievement of net zero targets, except when using removals to offset residual emissions (ISO 2022).
- The UN High Level Expert Group on the Net Zero Emissions Commitments of Non-State Entities suggests that carbon credits "cannot" be counted towards interim, science-aligned reduction targets, but they may be used to "counterbalance" residual emissions with removals to achieve net zero. At the same time, actors are strongly encouraged to use carbon credits to "balance out" their emissions prior to achieving net zero as long as they continue to meet interim targets (UN HLEG 2022).
- The SBTi Net Zero Standard adopts similar requirements, suggesting that carbon credits may be used to "neutralize" residual emissions but cannot be used as a substitute for meeting science-based emission reduction targets (SBTi 2023). In parallel, the SBTi developed a framework for "beyond value chain mitigation" (BVCM), which encourages (but does not require) actors to contribute to additional mitigation efforts, including through the use of carbon credits (Benson et al. 2024).

Prescribing a mitigation hierarchy guards against the risk that actors will use carbon credits in lieu of making needed investments in decarbonizing their value chains or economies. The hierarchy ensures that credits are only used for mitigation beyond prescribed targets or in circumstances where direct reductions are truly infeasible.

However, most net-zero plans treat "beyond value chain mitigation" as optional because it adds extra costs to already ambitious goals. This raises concerns that strict

mitigation hierarchies could reduce how much companies are willing to invest in global mitigation efforts, especially in developing countries. In addition, requiring companies to fully decarbonize their value chains in line with science-based targets may discourage action altogether, since many see these targets as too difficult to achieve (Broekhoff and Verkuijl 2024).

To respond to these concerns, the Voluntary Carbon Markets Integrity Initiative (VCMI) developed a framework in 2023 that seeks to recognize companies for ambitious use of carbon credits. The framework requires companies to set and achieve science-aligned targets for their value chain emissions and recognizes companies that purchase and retire carbon credits in proportion to their remaining emissions (VCMI 2025b). In conjunction, the VCMI has proposed a scheme under which companies that are failing to meet targets for their broader value chain ("Scope 3") emissions—which are often the most difficult to influence—may still receive recognition if they use carbon credits to bridge the gap (VCMI 2025a).

The VCMI's approach simultaneously seeks to incentivize ambitious use of carbon credits in line with a mitigation hierarchy while creating space to use credits to offset emissions where a company is off track in its targets. However, few companies have signed up for certification under the VCMI, and their approach of allowing carbon credits when participants fail to meet value chain targets has been criticized as too lenient (Dufrasne 2024).

Sorting out voluntary claims related to carbon credit use

As some terminology used by net zero initiatives may suggest (e.g., carbon credits may "neutralize," "balance out," "counterbalance," or "compensate for" emissions), the introduction of a mitigation hierarchy has spurred related debates about how companies should characterize their use of carbon credits (Trouwloon et al. 2023; Kreibich et al. 2022). Although carbon credits have conventionally been used for offsetting, a contingent of civil society groups has argued that risks of mitigation deterrence could be reduced if they are treated simply as a form of mitigation finance, or "mitigation contributions," without any implied offsetting claims (Carbon Market Watch 2025; Blanchard et al. 2024).

There are multiple arguments for this. Initial proposals to treat carbon credits as "contributions" arose from concerns about double claiming under the Paris Agreement (Kreibich and Obergassel 2019). Double claiming can occur when both a credit buyer and a national government count the same mitigation towards their respective GHG reduction targets. This double counting arguably makes offsetting claims untenable (although this has been hotly debated within the VCM). However, a buyer could still legitimately claim to be "contributing" to the achievement of the national government's mitigation targets (Kreibich and Hermwille 2021; Fearnehough et al. 2020; Brander et al. 2022; Broekhoff et al. 2024).

Apart from potential double claiming, the idea of making "contributions" is implied by arguments that companies should follow a mitigation hierarchy and only use carbon credits to support "beyond value chain mitigation." Some observers argue that using carbon credits simply to contribute to global mitigation is conceptually more defensible than offsetting (Gillenwater 2024).

A final argument is based on carbon credit quality concerns. According to this argument, treating carbon credits as mitigation "contributions" can avoid the reputational risks of (intentionally or unintentionally) using low-quality credits to make offsetting claims, which imply that real reductions in a company's own emissions were displaced by false assertions about external mitigation impacts. Contributions, by contrast, imply mitigation that is above and beyond what companies have committed to with respect to reducing their value chain emissions, avoiding any risk of a tradeoff (Chagas et al. 2025a; Macintosh et al. 2025a; Blanchard et al. 2024; Benson et al. 2024).

Despite these arguments, the VCM has been reluctant to embrace contribution claims. Such claims are widely perceived to be less valuable than offsetting or compensation claims. Thus, although the debate may seem semantic, it has practical implications. A shift to contribution claims, for example, may make companies less inclined to use carbon credits and depress demand for them. Further work is needed to clarify the definition and value of appropriate claims and identify options that support companies and other organizations to pursue climate action in ways that adequately address concerns about mitigation deterrence (Chagas et al. 2025a).

Part 3: Future directions

Three decades of experience illustrate the promise and perils of using project-based carbon credit markets to drive action on climate change. On the one hand, regulatory and voluntary markets around the world have mobilized billions of dollars of investment in projects that have deployed renewable energy, eliminated large sources of industrial GHGs and methane, enhanced energy efficiency, protected forests and other ecosystems, removed CO_2 from the atmosphere, and generated multiple human health and environmental benefits. On the other hand, these markets have suffered from persistent concerns that their benefits have been overstated and that they have distracted from (what could have been) more productive mitigation efforts.

This lack of perfection does not mean these markets are not useful. Multiple studies, for example, have found that two major project categories—clean cookstoves and avoided deforestation projects—have reduced emissions and provided benefits to local communities, despite being issued too many credits (Tang et al. 2025; Floess et al. 2023; Gill-Wiehl et al. 2024; Greenfield 2025). This suggests the need for constructive reform and engagement, not abandonment. Carbon credit markets are likely to remain an essential mechanism for facilitating voluntary climate action and continue to serve as a key tool for policymakers to attract carbon finance, complement carbon pricing policies, and drive mitigation investments in priority sectors, including nature-based climate solutions. They need to be developed and regulated with imperfections in mind and with an eye towards larger policy objectives.

Looking forward, it is important to understand what can be done to further improve carbon market performance and how to manage risks related to low credit quality and mitigation deterrence. Key areas for future development include continued support for emerging governance bodies and market infrastructure, improving government oversight and regulation, and continued development of a common architecture for carbon credit markets under Article 6.

FURTHER DEVELOPING CARBON CREDIT MARKET GOVERNANCE AND INFRASTRUCTURE

Current governance of carbon credit markets is a patchwork of governmental and non-governmental actors offering certifications, standards, and guidance that are often unaligned with wider regulatory frameworks and policy objectives (Johnstone et al. 2025; Ahonen et al. 2022). This decentralized governance may be partly responsible for ongoing quality challenges and debates around responsible use of carbon credits. It makes it difficult for markets to align around common mitigation priorities and the policy tradeoffs that come with them.

Various non-governmental initiatives are moving towards consolidated governance structures. As noted above, multiple independent oversight bodies and rating services are beginning to address quality issues and bring greater transparency to the VCM. They are also continuing to address and find common ground on questions related to appropriate uses and claims for carbon credits. It may take time for these initiatives to coalesce around common criteria, but they are already having a positive effect in raising quality standards.

Greater alignment in carbon credit markets may also be aided by initiatives that enable these markets to scale based on common standards, infrastructure, and objectives. For example, the Coalition to Grow Carbon Markets (a project of the VCMI) was launched in 2025 to help develop market infrastructure needed to support greater confidence, including transparency initiatives, data platforms, rating services, insurance, and risk management tools (Coalition to Grow Carbon Markets 2025). In addition, governments and multilateral institutions like the World Bank are establishing data systems, such as the Climate Action Data Trust and Common Data Open Protocol, to facilitate interoperability across registries and carbon crediting programs (Carbon Markets Infrastructure Working Group 2025; World Bank and Carbon Markets Infrastructure Working Group 2025).

Another emerging practice that could help align carbon credit markets and increase their impact is the formation of carbon credit buyers' coalitions and related investment vehicles, which pool capital to support large-scale forward purchasing commitments. Examples include the Frontier coalition, which targets development of engineered, high-durability removal activities, and Symbiosis, a large-scale coalition focused on advance market commitments for nature-based removals.[13] The LEAF Coalition pools private sector and government funding to support jurisdiction-wide efforts to stop tropical deforestation. The now-dormant Energy Transition Accelerator—a U.S. government-supported initiative that aimed to use carbon credits to support power sector transitions (including coal plan retirements) in developing countries—established guidance and methodologies that could be leveraged in the future.[14]

Demand aggregation of this sort has the potential to drive decarbonization in hard-to-abate sectors and enable sectoral transitions (Axelsson, Wigg, et al. 2024). These approaches are increasingly being endorsed by initiatives like Oxford Net Zero (Axelsson, Wagner, et al. 2024) and the Coalition to Grow Carbon Markets, which advocates for "engaging in buyers' and investors' networks to aggregate and scale demand, including through advanced purchase commitments and innovative financing models, to help channel capital into emerging markets and developing economies through impactful and fair transactions" (Coalition to Grow Carbon Markets 2025).

Other innovations in market infrastructure could also help to boost confidence and alignment around common standards. New insurance mechanisms, along with carbon credit portfolio management practices, promise better management of over-crediting risks (Cabiyo and Field 2025). Likewise, to address ongoing permanence concerns, the American Forest Foundation is exploring development of a global "permanence trust" that could fund long-term monitoring and compensation for projects subject to reversal risks (Truitt and Riley 2025).

IMPROVING GOVERNMENT OVERSIGHT AND REGULATION

Ultimately, governments and multilateral institutions are best positioned to provide robust governance and oversight of carbon credit markets. Governments can facilitate harmonization of standards for credit quality, including alignment with standards being developed under the PACM, and establish regulatory guardrails for upholding these standards (Wetterberg et al. 2025; Johnstone et al. 2025). This is the goal, for example, of the UNDP's High-Integrity Carbon Markets Initiative (UNDP 2023). Governments can clarify in legal terms how companies may credibly use carbon credits (including associated claims), identify priorities for voluntary climate action, and promote international collaboration in the use of carbon markets (Wetterberg et al. 2025). Through regulation, they can also identify a clear policy role for carbon markets (including the VCM) and help ensure they operate efficiently, effectively, and in line with global climate goals (Johnstone et al. 2025). International initiatives like the recently announced Open Coalition on Compliance Carbon Markets could help to foster a robust network of governmental oversight.[15]

Examples of advances in government oversight include the U.K., the EU, and Australia. For voluntary markets, this oversight has often taken the form of regulating consumer-facing claims based on carbon offsetting. For example, in the U.K., the Committee of Advertising Practice issued guidance requiring advertisers to specify whether climate claims are based on offsetting (CAP 2023). The EU has taken the more sweeping step of banning all claims that a product is "net-zero" or "carbon neutral" based on offsetting (Directive EU 2024/825 2024). In adopting regulations, governments often seek to ensure accountability for actors who abuse carbon markets, although some measures may create a perception of reputational risk that discourages well-meaning companies from engaging with the VCM.

MOVING TOWARDS INTEGRATION

Finally, governments and multilateral institutions can actively support efforts to integrate voluntary and compliance markets. Governments in the U.K., EU, and Australia have created government-administered, project-based carbon credit markets designed to serve voluntary demand. In the U.K., the government-administered Woodland Carbon Code (WCC) provides methodologies for nature-based removal projects intended for the voluntary market. The mechanism is paired with a £50 million fund to guarantee demand by allowing project developers to sell credits directly to the government (Wetterberg et al. 2024). The EU's Carbon Removal and Carbon Farming Regulation (CRCF) is a similar program designed to build a pipeline of high-quality removal credits (Regulation EU 2024/3012). The Australian Carbon Credit Unit (ACCU) Scheme is a government-administered voluntary carbon crediting program supporting mitigation projects in the energy, transport, and land-use sectors.

While these programs are designed to serve voluntary demand, they lay a foundation for regulatory compliance. Credits issued under the ACCU Scheme, for example, can be used by large industrial facilities to comply with Australia's Safeguard Mechanism (Clean Energy Regulator 2025). In the future, WCC and CRCF credits may similarly qualify for meeting regulatory obligations. These kinds of programs—which could be replicated in the U.S. and other jurisdictions—promote the alignment of voluntary and compliance markets around common policy objectives.

Further opportunities for integrating voluntary and compliance markets are arising under Article 6 of the Paris Agreement. Some governments, including Colombia and South Africa, already accept credits issued by independent crediting programs for meeting compliance obligations under domestic carbon pricing programs (Verra, n.d.). This practice could grow, as multiple countries look to these programs to generate credits that may be traded as ITMOs under Article 6.2. The Article 6.2 Crediting Protocol, co-developed by the government of Singapore and two independent crediting programs (the Gold Standard and Verra), clarifies how governments can utilize third-party registry systems to implement ITMO trades (Verra 2025b). ICAO has already set a precedent for this by recognizing independent carbon credits—backed by Corresponding Adjustments from host countries—for compliance under the CORSIA program.

Relying on independent crediting programs affords governments a "turnkey" option to participate in international carbon markets under Article 6 without needing to invest in separate domestic program architecture and administrative systems (PMR 2015; Partnership for Market Readiness 2021). At the same time, by establishing rules and procedures for what kinds of projects they will authorize for Article 6.2 trades, they can help steer investment from both compliance and voluntary buyers (who may be inclined to seek recognition for supporting government policy objectives). Over time, this could lead to growing convergence between compliance and voluntary markets.

In a similar vein, standards developed under Article 6 could help to address carbon credit quality issues across compliance and voluntary markets. Proposed methodological standards under the PACM, for example, seek to rectify shortcomings that plagued the CDM by requiring rigorous additionality tests, baselines aligned with Paris Agreement goals, stringent monitoring and accounting practices, and robust procedures for governance and stakeholder consultations (UNFCCC 2025a, 2025b, 2025c). Whether these standards set a common bar for quality will depend on how widely they are adopted, including under Article 6.2, which allows countries to mutually agree to alternative crediting standards from the PACM. Ultimately, the convergence and integration of carbon credit markets will hinge on governments agreeing to common standards and objectives.

Conclusion

Achieving climate targets will require leveraging mitigation opportunities across sectors, investing in nature-based solutions, and deploying durable carbon removal (IPCC 2022). Effective project-based carbon credit markets could be key tools for realizing these goals. Decades of experience demonstrate that carbon credit markets are valuable but imperfect instruments. Historically, they have often been designed poorly and used irresponsibly in ways that undermine their integrity and effectiveness. However, with proper support, oversight, and regulation, they can serve as effective mechanisms to advance policy objectives, support mitigation, and provide climate finance to countries and communities in need.

The heightened scrutiny of credit quality that has emerged in recent years provides an opportunity to reform markets towards greater environmental integrity. Initiatives like the Integrity Council for the Voluntary Carbon Market, the development of third-party rating services, and the tightening of standards under Article 6.4 all represent important steps toward building more impactful markets. Government-administered voluntary crediting programs, like the U.K.'s Woodland Carbon Code and the EU's Carbon Removal and Carbon Farming program, could also play an important role in expanding high-quality supply. Continued academic research investigating carbon credit quality will be crucial for assessing the effectiveness of these measures.

Recent criticism levied at the irresponsible use of carbon credits also offers a necessary push for companies and governments to reassess the role of carbon credits in broader climate strategies. Carbon credits have often been used to make misleading claims about companies' progress in decarbonizing their own operations. These claims have at times backfired, inviting legal and reputational scrutiny and undermining trust in carbon credit markets. The adoption of mitigation hierarchies, aimed at ensuring carbon credits are only used to provide additional contributions to global mitigation or offset hard-to-abate emissions, offer a promising roadmap for responsible use. An increasing number of governments are also regulating claims made using carbon credits, protecting consumers while providing legal clarity for corporate buyers.

Going forward, governments can continue to play an important role in supporting and developing carbon credit markets. Active governance and oversight are needed to support trust and integrity. Governments can help align markets under common standards and build market infrastructure like shared registry systems and buyers coalitions. High-quality carbon credit markets can provide governments with a valuable tool to complement and enhance current and future climate policies. While carbon credit markets cannot replace carbon pricing or regulation, they can enable ambitious voluntary action and provide an effective means to drive decarbonization in sectors where regulation is not feasible.

References

ACR. 2023. "American Carbon Registry Is Now ACR." ACR, September 27. https://acrcarbon.org/news/american-carbon-registry-is-now-acr/.

Ahonen, Hanna-Mari, Juliana Kessler, Axel Michaelowa, Aglaja Espelage, and Stephan Hoch. 2022. "Governance of Fragmented Compliance and Voluntary Carbon Markets Under the Paris Agreement." Politics and Governance 10 (1): 235–45. https://doi.org/10.17645/pag.v10i1.4759.

Astana International Financial Centre. 2025. Emissions Trading Systems and Voluntary Carbon: Global Overview and Prospects for Kazakhstan. Astana. https://aifc.kz/wp-content/uploads/2025/02/emissions-trading-systems-and-voluntary-carbon-market-global-overview-and-prospects-for-kazakhstan.pdf.

Akerlof, George. 1970. "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism." Quarterly Journal of Economics 84 (3): 488–500.

Allen, Myles R., David J. Frame, Chris Huntingford, et al. 2009. "Warming Caused by Cumulative Carbon Emissions towards the Trillionth Tonne." Nature 458 (7242): 1163–66. https://doi.org/10.1038/nature08019.

Anderegg, William R. L., Anna T. Trugman, German Vergas G., Chao Wu, and Linqing Yang. 2025. "Current Forest Carbon Offset Buffer Pool Contributions Do Not Adequatly Insure Against Disturbance-Driven Carbon Losses." Global Change Biology 31 (6). https://onlinelibrary.wiley.com/doi/10.1111/gcb.70251.

Arcusa, Stephanie H., and Klaus S. Lackner. 2025. "Carbon Sequestration Ought to Be Permanent on Climate-Relevant Timescales." Environmental Science & Policy 173 (November): 104223. https://doi.org/10.1016/j.envsci.2025.104223.

Atal, Raimundo, and Derek Sylvan. 2025. Integrity, Equivalence, and Imperfect Carbon Offsets: Implications for Carbon Markets and Net-Zero Claims. Institute for Policy Integrity. https://policyintegrity.org/files/publications/Integrity_Equivalence_and_Imperfect_Carbon_Offsets.pdf.

Axelsson, Kaya, Audrey Wagner, Injy Johnstone, et al. 2024. The Oxford Principles for Net Zero Aligned Carbon Offsetting (Revised 2024). University of Oxford. https://www.smithschool.ox.ac.uk/sites/default/files/2024-02/Oxford-Principles-for-Net-Zero-Aligned-Carbon-Offsetting-revised-2024.pdf.

Axelsson, Kaya, Claire Wigg, and Matilda Becker. 2024. "Is Impact out of Scope? A Call for Innovation in Climate Standards to Inspire Action across Companies' Spheres of Influence." Carbon Management 15 (1): 2382995. https://doi.org/10.1080/17583004.2024.2382995.

Badgley, Grayson, Freya Chay, Oriana S. Chegwidden, Joseph J. Hamman, Jeremy Freeman, and Danny Cullenward. 2022. "California's Forest Carbon Offsets Buffer Pool Is Severely Undercapitalized." Frontiers in Forests and Global Change 5 (August). https://doi.org/10.3389/ffgc.2022.930426.

Barbato, Clare T., and Aaron L. Strong. 2023. "Farmer Perspectives on Carbon Markets Incentivizing Agricultural Soil Carbon Sequestration." Npj Climate Action 2 (1): 26. https://doi.org/10.1038/s44168-023-00055-4.

Bassetti, Francesco. 2022. "Success or Failure? The Kyoto Protocol's Troubled Legacy." Foresight, December 8. https://www.climateforesight.eu/articles/success-or-failure-the-kyoto-protocols-troubled-legacy/.

Benson, Scarlett, Alice Farrelly, Emma Watson, et al. 2024. Above and beyond: An SBTi Report on the Design and Implementation of beyond Value Chain Mitigation (BVCM). Version 1.0. Science Based Targets initiative. https://sciencebasedtargets.org/beyond-value-chain-mitigation.

Berends, Michael, Nico Curtis, Donna Lee, et al. 2025. The State of Quality and Pricing in the VCM. Calyx Global and ClearBlue Markets. https://www.clearbluemarkets.com/news/new-report-a-turning-point-for-carbon-credit-quality-pricing.

Berrin v. Delta Airlines, Inc., No. 2:23-cv-04150-MEMF-MRW (United States District Court for the Central District of California May 30, 2023). https://www.climatecasechart.com/documents/class-action-lawsuit-claimed-delta-misrepresented-that-it-was-carbon-neutral-airline_1bd1.

Blanchard, Libby, William R. L. Anderegg, and Barbara K. Haya. 2024. Instead of Carbon Offsets, We Need

'Contributions' to Forests (SSIR). January 31. https://ssir.org/articles/entry/forest-contributions-carbon-offsets.

Brander, Matthew, Derik Broekhoff, and Owen Hewlett. 2022. "The Future of the Voluntary Offset Market: The Need for Corresponding Adjustments." Edinburgh Research Explorer, April 29. https://www.research.ed.ac.uk/en/publications/the-future-of-the-voluntary-offset-market-the-need-for-correspond/.

Broekhoff, Derik, Michael Gillenwater, Tani Colbert-Sangree, and Patrick Cage. 2024. Securing Climate Benefit: A Guide to Using Carbon Credits (Second Edition). Stockholm Environment Institute & Greenhouse Gas Management Institute. Offsetguide.org/pdf-download/.

Broekhoff, Derik, and Randall Spalding-Fecher. 2021. "Assessing Crediting Scheme Standards and Practices for Ensuring Unit Quality under the Paris Agreement." Carbon Management, ahead of print, October 29. https://doi.org/10.1080/17583004.2021.1994016.

Broekhoff, Derik, and Cleo Verkuijl. 2024. Making Good on Financial Sector Net Zero Commitments: Building the Road to Policy. Stockholm Environment Institute. https://doi.org/10.51414/sei2024.045.

Broekhoff, Derik, and Kathryn Zyla. 2008. Outside The Cap: Opportunities and Limitations of Greenhouse Gas Offsets. World Resources Institute. https://www.wri.org/research/outside-cap.

Brunner, Cyril, Zeke Hausfather, and Reto Knutti. 2024. "Durability of Carbon Dioxide Removal Is Critical for Paris Climate Goals." Communications Earth & Environment 5 (1): 645. https://doi.org/10.1038/s43247-024-01808-7.

Bushnell, James B. 2011. "The Economics of Carbon Offsets." Preprint, University of Chicago Press, September. https://www.nber.org/books-and-chapters/design-and-implementation-us-climate-policy/economics-carbon-offsets.

Cabiyo, Bodie, and Christopher B. Field. 2025. "Embracing Imperfection: Carbon Offset Markets Must Learn to Mitigate the Risk of Overcrediting." PNAS Nexus 4 (5): pgaf091. https://doi.org/10.1093/pnasnexus/pgaf091.

Calel, Raphael, Jonathan Colmer, Antoine Dechezleprêtre, and Matthieu Glachant. 2021. "Do Carbon Offsets Offset Carbon?" CESifo Working Paper No. 9368. Preprint, Social Science Research Network. https://doi.org/10.2139/ssrn.3950103.

Calyx Global. 2025. An Introduction to Jurisdictional REDD. February 25. https://calyxglobal.com/research-hub/research/an-introduction-to-jurisdictional-REDD/.

Calyx Global, and Clear Blue Markets. 2026. State of Quality and Pricing in the VCM 2026. https://www.clearbluemarkets.com/the-state-of-quality-and-pricing-in-the-vcm-report.

Cames, Martin, Ralph O. Harthan, Jürg Füssler, et al. 2016. How Additional Is the Clean Development Mechanism? Analysis of the Application of Current Tools and Proposed Alternatives. Öko-Institut. https://climate.ec.europa.eu/system/files/2017-04/clean_dev_mechanism_en.pdf.

Cames, Martin, Ralph O. Harthan, Jurg Fussler, et al. 2016. How Additional Is the Clean Development Mechanism? Analysis of the Application of Current Tools and Proposed Alternatives. CLIMA.B.3/SERI2013/0026r. Prepared for DG Clima by Oko-Institut, INFRAS, Stockholm Environment Institute (SEI). https://climate.ec.europa.eu/system/files/2017-04/clean_dev_mechanism_en.pdf.

Committee of Advertising Practice. 2023. "Updated Environment Guidance: Carbon Neutral and Net Zero Claims in Advertising." Committee of Advertising Practice, February 10. https://www.asa.org.uk/news/updated-environment-guidance-carbon-neutral-and-net-zero-claims-in-advertising.html.

California Air Resources Board. 2024. "The Fourth Compliance Period (CP4) Compliance Report." California Air Resources Board, December 6. https://ww2.arb.ca.gov/resources/documents/fourth-compliance-period-cp4-compliance-report.

Carbon Markets Infrastructure Working Group. 2025. Technical Guidance Note Enhancing Data and Systems Interoperability for Carbon Markets: Current Landscape and Strategic Recommendations. Washington, DC: World Bank. https://climateactiondata.org/resources/.

Carbon Offset Guide. n.d. "What Are Carbon Crediting Programs." Greenhouse Gas Management and Stockholm

Environment Institute. Accessed April 24, 2026. https://offsetguide.org/what-are-carbon-crediting-programs/.

Carew, Sam. 2024. "The State of the Voluntary Carbon Market." Fastmarkets, December 5. https://www.fastmarkets.com/insights/the-state-of-the-voluntary-carbon-market/.

Chagas, Thiago, Charlotte Streck, and Danick Trouwloon. 2025a. "Ensuring Environmental Integrity of Voluntary Carbon Market Claims: Understanding and Framing VCM Contribution Claims." Climate Policy 0 (0): 1–17. https://doi.org/10.1080/14693062.2025.2557234.

Chagas, Thiago, Charlotte Streck, and Danick Trouwloon. 2025b. "Ensuring Environmental Integrity of Voluntary Carbon Market Claims: Understanding and Framing VCM Contribution Claims." Climate Policy 0 (0): 1–17. https://doi.org/10.1080/14693062.2025.2557234.

Chan, Gabriel Angelo Sherak. 2015. "Essays on Energy Technology Innovation Policy." Ph.D. thesis. https://ui.adsabs.harvard.edu/abs/2015PhDT.....209C.

Chemnick, Jean. 2020. "'Utter Failure.' How Carbon Tax Lost Its Allure." E&E News by POLITICO, February 27. https://www.eenews.net/articles/utter-failure-how-carbon-tax-lost-its-allure/.

Clean Energy Regulator. 2025. "Australian Carbon Credit Unit Scheme." May 6. https://cer.gov.au/schemes/australian-carbon-credit-unit-scheme.

Clean Energy Regulator. 2025. 2023-24 Safeguard Data Insights. Australian Government Clean Energy Regulator. https://cer.gov.au/document/2023-24-safeguard-data-insights-0.

Coalition to Grow Carbon Markets. 2025. Shared Principles for Growing High-Integrity Use of Carbon Credits by Companies and Other Buyers. https://coalitiontogrowcarbonmarkets.org/shared-principles/.

Coase, R. H. 1960. "The Problem of Social Cost." The Journal of Law & Economics 3: 1–44.

Coffield, Shane R., Cassandra D. Vo, Jonathan A. Wang, et al. 2022. "Using Remote Sensing to Quantify the Additional Climate Benefits of California Forest Carbon Offset Projects." Global Change Biology 28 (22). https://doi.org/10.1111/gcb.16380.

Colmer, Jonathan, Ralf Martin, Mirabelle Muûls, and Ulrich J. Wagner. 2024. "Does Pricing Carbon Mitigate Climate Change? Firm-Level Evidence from the European Union Emissions Trading System." The Review of Economic Studies 92 (3): 1625–60. https://doi.org/10.1093/restud/rdae055.

Crippa, Monica, Diego Guizzardi, Federico Pagani, et al. 2024. GHG Emissions of All World Countries. European Union. https://doi.org/10.2760/4002897.

Crocker, Thomas D. 1966. "The Structuring of Atmospheric Pollution Control Systems." In The Economics of Air Pollution. W. W. Norton.

Cullenward, Danny. 2023. A Framework for Assessing the Climate Value of Temporary Carbon Storage. Carbon Market Watch. https://carbonmarketwatch.org/publications/a-framework-for-assessing-the-climate-value-of-temporary-carbon-storage/.

Cullenward, Danny, Grayson Badgley, and Freya Chay. 2023. "Carbon Offsets Are Incompatible with the Paris Agreement." One Earth 6 (9): 1085–88. https://doi.org/10.1016/j.oneear.2023.08.014.

Dales, John H. 1968. Pollution, Property and Prices. University of Toronto Press.

Day, Thomas, Silke Mooldijk, Frederic Hans, et al. 2023. Corporate Climate Responsibility Monitor 2023: Assessing the Transparency and Integrity of Companies' Emission Reduction and Net-Zero Targets. New Climate Institute. https://newclimate.org/resources/publications/corporate-climate-responsibility-monitor-2023.

Day, Thomas, Silke Mooldijk, Sybrig Smit, et al. 2022. Corporate Climate Responsibility Monitor 2022: Assessing the Transparency and Integrity of Companies' Emission Reduction and Net-Zero Targets. New Climate Institute and Carbon Market Watch. https://newclimate.org/resources/publications/corporate-climate-responsibility-monitor-2022.

De Grandpré, Juliette, and Joshua Senne. 2026. "How Article 6 Could Undermine Climate Ambition." New Climate Institute, March 5. https://newclimate.org/news/how-article-6-could-undermine-climate-ambition.

Delta Airlines. 2023. 2023 ESG Report. Delta Airlines. https://esghub.delta.com/content/dam/esg/2023/pdf/Delta-2023-ESG-Report.pdf.

Department of Environmental Quality. 2026. "Community Climate Investments." https://www.oregon.gov/deq/ghgp/cpp/Pages/Community-Climate-Investments.aspx.

Department of State. 1998. "United States Signs the Kyoto Protocol." U.S. Department of State, November 12. https://1997-2001.state.gov/global/global_issues/climate/fs-us_sign_kyoto_981112.html.

Directive 2004/101/EC, European Parliment, 338 OJ L (2004). http://data.europa.eu/eli/dir/2004/101/oj.

Directive (EU) 2024/825 of the European Parliament and of the Council of 28 February 2024 Amending Directives 2005/29/EC and 2011/83/EU as Regards Empowering Consumers for the Green Transition through Better Protection against Unfair Practices and through Better Information, Pub. L. No. PE/64/2023/REV/1, PE/64/2023/REV/1 PE/64/2023/REV/1 (2024). http://data.europa.eu/eli/dir/2024/825/oj.

Döbbeling-Hildebrandt, Niklas, Klaas Miersch, Tarun M. Khanna, et al. 2024. "Systematic Review and Meta-Analysis of Ex-Post Evaluations on the Effectiveness of Carbon Pricing." Nature Communications 15 (1): 4147. https://doi.org/10.1038/s41467-024-48512-w.

Dossi, Federica, and Jonathan Crook. 2025. By the Book: How Effective Are Article 6 Carbon Market Rules? Carbon Market Watch. https://carbonmarketwatch.org/publications/by-the-book-how-effective-are-article-6-carbon-market-rules/.

Dufrasne, Gilles. 2024. "VCMI's New Framework Needlessly Endangers Its Credibility." Carbon Market Watch, September 2. https://carbonmarketwatch.org/2024/09/02/vcmis-new-framework-needlessly-endangers-its-credibility/.

Dyson, Freeman J. 1977. "Can We Control the Carbon Dioxide in the Atmosphere?" Energy 2 (3): 287–91. https://doi.org/10.1016/0360-5442(77)90033-0.

Enríquez-de-Salamanca, Álvaro. 2024. "Environmental and Social Impacts of Carbon Sequestration." Integrated Environmental Assessment and Management 20 (6): 1812–38. https://doi.org/10.1002/ieam.4925.

European Commission. n.d. "Development of EU ETS (2005-2020)." European Commission. Accessed January 16, 2026. https://climate.ec.europa.eu/eu-action/carbon-markets/eu-emissions-trading-system-eu-ets/development-eu-ets-2005-2020_en.

Fearnehough, Harry, Aki Kachi, Silke Mooldijk, Carsten Warnecke, and Lambert Schneider. 2020. Future Role for Voluntary Carbon Markets in the Paris Era. Umweltbundesamt. https://www.umweltbundesamt.de/en/publikationen/future-role-for-voluntary-carbon-markets-in-the.

Ferris, Nick. 2024. "Shell's Dominance of the Voluntary Carbon Market Drives Retirements Surge." Carbon Pulse, May 29. https://carbon-pulse.com/290185/.

Floess, Emily, Andrew Grieshop, Elisa Puzzolo, et al. 2023. "Scaling up Gas and Electric Cooking in Low- and Middle-Income Countries: Climate Threat or Mitigation Strategy with Co-Benefits?" Environmental Research Letters 18 (3): 034010. https://doi.org/10.1088/1748-9326/acb501.

Food and Agriculture Organization. 1995. State of the World's Forests. Food and Agriculture Organization. https://www.fao.org/4/x6953e/X6953E00.htm#TOC.

Food and Agriculture Organization. 2024. Options for Addressing the Risk of Non-Permanence for Land-Based Mitigation in Carbon Crediting Programmes. Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/cd3083en.

Forest Trends' Ecosystem Marketplace. 2022. The Art of Integrity: State of Voluntary Carbon Markets, Q3 Insights Briefing. Forest Trends Association. https://www.ecosystemmarketplace.com/publications/state-of-the-voluntary-carbon-markets-2022/.

Forest Trends' Ecosystem Marketplace. 2024. State of the Voluntary Carbon Market 2024. Forest Trends Association. https://www.ecosystemmarketplace.com/publications/2024-state-of-the-voluntary-carbon-markets-sovcm/.

Forest Trends' Ecosystem Marketplace. 2025. State of the Voluntary Carbon Market 2025. Forest Trends

Association. https://www.forest-trends.org/publications/2025-state-of-the-voluntary-carbon-market/.
Fursman, Lindy, Hermione Dace, and Matthew MacGeoch. 2025. International Carbon Markets: Climate Action at a Lower Price. Tony Blair Institute for Global Change. https://institute.global/insights/climate-and-energy/international-carbon-markets-climate-action-at-a-lower-price.
Gabbatiss, Josh, and Tom Pearson. 2023. "Analysis: How Some of the World's Largest Companies Rely on Carbon Offsets to 'Reach Net-Zero.'" Carbon Brief, September 28. https://interactive.carbonbrief.org/carbon-offsets-2023/companies.html.
Giles, Cynthia, and Cary Coglianese. 2025. "Auditors Can't Save Carbon Offsets." Science 389 (6756): 107–107. https://doi.org/10.1126/science.ady4864.
Gillenwater, Michael. 2012. "What Is Additionality." Greenhouse Gas Management Institute, no. Discussion Paper No. 001 (January). https://ghginstitute.org/wp-content/uploads/2015/04/AdditionalityPaper_Part-1ver3FINAL.pdf#page=11.
Gillenwater, Michael. 2024. "Do We Need a Paradigm Shift on Offsetting? Compensation to Contributions." Greenhouse Gas Management Institute, July 13. https://ghginstitute.org/2024/07/13/do-we-need-a-big-conceptual-shift-on-offsetting-compensation-to-contributions/.
Gillenwater, Michael, Derik Broekhoff, Mark Trexler, Jasmine Hyman, and Rob Fowler. 2007. "Policing the Voluntary Carbon Market." Nature Reports Climate Change, no. 0711 (November): 85–87. https://doi.org/10.1038/climate.2007.58.
Gill-Wiehl, Annelise, Daniel M. Kammen, and Barbara K. Haya. 2024. "Pervasive Over-Crediting from Cookstove Offset Methodologies." Nature Sustainability, January 23, 1–12. https://doi.org/10.1038/s41893-023-01259-6.
Gonzalez, Gloria. 2013. "Disney To Expand Voluntary Carbon Offset Buying." Ecosystem Marketplace, September 13. https://www.ecosystemmarketplace.com/articles/disney-to-expand-br-voluntary-carbon-offset-buying/.
Granziera, Beatriz, Malvar Hamrick, and John Verdieck. 2025. Article 6 Explainer. The Nature Conservancy. https://www.nature.org/content/dam/tnc/nature/en/documents/c/m/CM-TNC-Article-6-Explainer.pdf.
Greenfield, Patrick. 2023. "Revealed: More than 90% of Rainforest Carbon Offsets by Biggest Certifier Are Worthless, Analysis Shows." Environment. The Guardian, January 18. https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe.
Greenfield, Patrick. 2025. "'There Is No Money': As Carbon Markets Collapse, What Happens to the Forests They Promised to Protect?" Environment. The Guardian, November 6. https://www.theguardian.com/environment/2025/nov/06/carbon-offsetting-market-collapses-what-happens-to-the-forests-they-hoped-to-protect-aoe.
Groom, Ben, and Frank Venmans. 2023. "The Social Value of Offsets." Nature, July 5, 1–6. https://doi.org/10.1038/s41586-023-06153-x.
Gupte, Eklavya. 2024. "Switzerland, Thailand Conclude First Article 6.2 Deal in Landmark Move for Carbon Markets." S&P Global Energy, August 1. https://www.spglobal.com/energy/en/news-research/latest-news/energy-transition/010824-switzerland-thailand-conclude-first-article-62-deal-in-landmark-move-for-carbon-markets.
Hale, Thomas, Stephen M. Smith, Richard Black, et al. 2022. "Assessing the Rapidly-Emerging Landscape of Net Zero Targets." Climate Policy 22 (1): 18–29. https://doi.org/10.1080/14693062.2021.2013155.
Harris, Steph. 2022. "What Just Happened? Distilling the Year That Was 2021 in the Voluntary Carbon Market." 3Degrees, February 26. https://3degreesinc.com/insights/what-just-happened-distilling-the-year-that-was-2021-in-the-voluntary-carbon-market/.
Haya, Barbara K., Tyler Bernard, Aline Abayo, Xinyun Rong, Ivy S. So, and Micah Elias. 2025. "Voluntary Registry Offsets Database." Versions 2025-06. https://gspp.berkeley.edu/berkeley-carbon-trading-project/offsets-database.
Haya, Barbara K., and Payal Parekh. 2011. Hydropower in the CDM: Examining Additionality and Criteria for

Sustainability. University of California, Berkeley. http://www.ssrn.com/abstract=2120862.
Hovi, Jon, Detlef F. Sprinz, and Guri Bang. 2010. "Why the United States Did Not Become a Party to the Kyoto Protocol: German, Norwegian, and US Perspectives." European Journal of International Relations 18: 129–50. https://doi.org/10.1177/1354066110380964.
Hunter, David, and Melissa Powers. 2013. "The Kyoto Protocol." In Climate Change and the Law, 2nd ed. Lexis-Nexis. https://law.lclark.edu/live/files/14375-chapter-5-kp-finalpdf.
International Civil Aviation Organization. 2022. CORSIA Eligible Emissions Units. International Civil Aviation Organization. https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Emissions-Units.aspx.
International Civil Aviation Organization. 2024a. "CORSIA Eligible Emissions Units." International Civil Aviation Organization, October. https://www2023.icao.int/environmental-protection/CORSIA/Documents/CORSIA%20Eligible%20Emissions%20Units/CORSIA_EEU_Oct2024.pdf.
International Civil Aviation Organization. 2024b. "CORSIA States for Chapter 3 State Pairs." International Civil Aviation Organization, September. https://www.icao.int/sites/default/files/2025-06/CORSIA-States-for-Chapter-3-State-Pairs_5Ed_Rev_web.pdf.
International Civil Aviation Organization. 2025. CONSOLIDATED STATEMENT OF CONTINUING ICAO POLICIES AND PRACTICES RELATED TO ENVIRONMENTAL PROTECTION – CARBON OFFSETTING AND REDUCTION SCHEME FOR INTERNATIONAL AVIATION. International Civil Aviation Organization. https://www.icao.int/sites/default/files/Meetings/a42/Documents/WP/wp_028_en.pdf.
International Carbon Action Partnership. 2025. Emissions Trading Worldwide: Status Report 2025. International Carbon Action Partnership. https://icapcarbonaction.com/en/publications/emissions-trading-worldwide-icap-status-report-2025.
Integrity Council for the Voluntary Carbon Market. 2023. Core Carbon Principles, Program-Level Assessment Framework, and Assessment Procedure. Integrity Council for the Voluntary Carbon Market. https://icvcm.org/the-core-carbon-principles/.
Integrity Council for the Voluntary Carbon Market. 2024. How Article 6 & the CCPs Work Together for Climate Action. November 7. https://icvcm.org/article-6-of-the-paris-agreement-and-the-integrity-councils-work/.
International Emissions Trading Association. 2021. GHG Market Sentiment Survey 2021. International Emissions Trading Association. https://www.ieta.org/uploads/wp-content/Resources/Reports/IETA_GHGSentimentSurvey_2021.pdf.
Intergovernmental Panel on Climate Change. 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.
Intergovernmental Panel on Climate Change. 2022. "Summary for Policymakers." In Climate Change 2022 - Mitigation of Climate Change: Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.
International Organization for Standardization. 2022. Net Zero Guidelines – Accelerating the Transition to Net Zero. First edition. International Organization for Standardization (ISO). https://www.iso.org/obp/ui/en/#iso:std:iso:iwa:42:ed-1:v1:en.
Jardine, Chloe. 2026. "UN Issues First Credits under Article 6.4's Pacm | Latest Market News." February 26. https://www.argusmedia.com/en/news-and-insights/latest-market-news/2793210-un-issues-first-credits-under-article-6.4-s-pacm.
Johnstone, Injy, Sindi Kuci, Thomas Hale, Varnika Chawla, and Kenneth Nicholas. 2025. Roadmap to Net-Zero Aligned Carbon Market Regulation. University of Oxford. https://netzeroclimate.org/publications/roadmap-to-net-zero-aligned-carbon-market-regulation/.
Kainou, Kazunari. 2022. Collapse of the Clean Development Mechanism Scheme under the Kyoto Protocol and Its Spillover: Consequences of 'Carbon Panic.' CEPR. https://cepr.org/voxeu/columns/collapse-clean-development-mechanism-scheme-under-kyoto-protocol-and-its-spillover.

Keeble, Justin. 2023. "Report: Executives Fear Greenwashing and the Economy Will Stall Sustainability Progress." Google Cloud Blog, April 12. https://cloud.google.com/transform/2023-google-cloud-sustainability-survey.

Kollmuss, Anja, and Benjamin Bowell. 2007. Voluntary Offsets For Air-Travel Carbon Emissions. Tufts Climate Initiative. https://sustainability.tufts.edu/wp-content/uploads/TCI_Carbon_Offsets_Paper_April-2-07.pdf.

Kollmuss, Anja, and Lambert Schneider. 2015. "Has Joint Implementation Reduced GHG Emissions? Lessons Learned for the Design of Carbon Market Mechanisms." SEI Working Paper No. 2015-07, August 24. https://www.sei.org/publications/has-joint-implementation-reduced-ghg-emissions-lessons-learned-for-the-design-of-carbon-market-mechanisms/.

Kreibich, Nicolas, Victoria Brandemann, and Franziska Jüde. 2022. Governing Corporate Claims: Increasing Transparency of Climate-Related Claims. Policy Paper. Wuppertal Institute. https://www.carbon-mechanisms.de/fileadmin/media/dokumente/Publikationen/Policy_Paper_03_2022_Claims.pdf.

Kreibich, Nicolas, and Lukas Hermwille. 2021. "Caught in between: Credibility and Feasibility of the Voluntary Carbon Market Post-2020." Climate Policy 0 (0): 1–19. https://doi.org/10.1080/14693062.2021.1948384.

Kreibich, Nicolas, and Wolfgang Obergassel. 2019. The Voluntary Carbon Market: What May Be Its Future Role and Potential Contributions to Ambition Raising? Discussion Paper. German Emissions Trading Authority (DEHSt) at the German Environment Agency. https://d-nb.info/1197125876/34.

La Hoz Theuer, Stephanie, Maia Hall, Alexander Eden, Emaa Krause, Constanze Haug, and Stefano De Clara. 2023. Offset Use Across Emissions Trading Systems. International Carbon Action Partnership. https://icapcarbonaction.com/system/files/document/ICAP%20offsets%20paper_vfin.pdf.

Legrady, Judit. 2025. "The Significance and Market Impact of CORSIA's 2025 Periodic Review." South Pole, June 19. https://www.southpole.com/blog/the-significance-and-market-impact-of-corsias-2025-periodic-review.

Loffler, Tristan, and Anubhav Joshi. 2025. 2025 State of Integrity in the Global Carbon-Credit Market. MSCI. https://www.msci.com/research-and-insights/paper/2025-state-of-integrity-in-the-global-carbon-credit-market.

Macintosh, Andrew, Don Butler, Pablo Larraondo, et al. 2024. "Australian Human-Induced Native Forest Regeneration Carbon Offset Projects Have Limited Impact on Changes in Woody Vegetation Cover and Carbon Removals." Communications Earth & Environment 5 (1): 149. https://doi.org/10.1038/s43247-024-01313-x.

Macintosh, Andrew, Gregory Trencher, Benedict Probst, et al. 2025a. "Carbon Credits Are Failing to Help with Climate Change — Here's Why." Nature 646 (8085): 543–46. https://doi.org/10.1038/d41586-025-03313-z.

Macintosh, Andrew, Gregory Trencher, Benedict Probst, et al. 2025b. "Carbon Credits Are Failing to Help with Climate Change — Here's Why." Nature 646 (8085): 543–46. https://doi.org/10.1038/d41586-025-03313-z.

Matthews, H. Damon, Kirsten Zickfeld, Alexander Koch, and Amy Luers. 2023. "Accounting for the Climate Benefit of Temporary Carbon Storage in Nature." Nature Communications 14 (1): 1. https://doi.org/10.1038/s41467-023-41242-5.

McCully, Patrick. 2008. "Discredited Strategy." Environment. The Guardian, May 20. https://www.theguardian.com/environment/2008/may/21/environment.carbontrading.

Ministry of Ecology and Environment. 2024. Progress Report of China's National Carbon Market (2024). Ministry of Ecology and Environment of the People's Republic of China. https://www.mee.gov.cn/ywdt/xwfb/202407/W020240722528850763859.pdf.

Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs. 2024. "Report on the 2021-2023 Compliance Period of the Québec Cap-and-Trade System for Greenhouse Gas Emission Allowances (C&T System)." Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs, December 6. https://www.environnement.gouv.qc.ca/changements/carbone/Couverture-en.htm.

Metcalf, Gilbert E., and James H. Stock. 2020. "Measuring the Macroeconomic Impact of Carbon Taxes." AEA Papers and Proceedings 110 (May): 101–6. https://doi.org/10.1257/pandp.20201081.

Michaelowa, Axel, Juliana Keßler, Sandra Dalfiume, and Hanna-Mari Ahonen. 2025. Reversal Risk and Buffer Pool Contribution Analysis. Discussion Paper. Perspectives Climate Group. https://perspectives.cc/wp-content/uploads/2025/06/PCG_Reversal-Risk-Paper_20250616-1.pdf.

Millard-Ball, Adam. 2013. "The Trouble with Voluntary Emissions Trading: Uncertainty and Adverse Selection in Sectoral Crediting Programs." Journal of Environmental Economics and Management 65 (1): 40–55. https://doi.org/10.1016/j.jeem.2012.05.007.

Montero, Juan-Pablo. 1999. "Voluntary Compliance with Market-Based Environmental Policy: Evidence from the U. S. Acid Rain Program." Journal of Political Economy 107 (5): 998–1033. https://doi.org/10.1086/250088.

Morales, Margaret. 2024. "4 Surprising Charts about Climate Targets from the World's 500 Largest Companies." Trellis, September 24. https://trellis.net/article/4-surprising-charts-about-climate-targets-from-the-worlds-500-largest-companies/.

Mulder, Isa. 2025. "Carbon Market Supporters Risk Cheating the Nature They Wish to Protect." Climate Home News, November 11. https://www.climatechangenews.com/2025/11/11/carbon-market-supporters-risk-cheating-the-nature-they-wish-to-protect/.

Mulkern, Anne C. 2011. "Offsets Could Make Up 85% of Calif.'s Cap-And-Trade Program." The New York Times, August 8. https://archive.nytimes.com/www.nytimes.com/gwire/2011/08/08/08greenwire-offsets-could-make-up-85-of-califs-cap-and-tra-29081.html?pagewanted=3.

Padin-Dujon, Alejandra. 2025. "FEATURE: 'Avoided' Emissions Confusion Hangs over International Carbon Markets." Carbon Pulse, January 28. https://carbon-pulse.com/361095/.

Palazzo, Berardino. 2023. Corporate Profits in the Aftermath of COVID-19. September 8. https://www.federalreserve.gov/econres/notes/feds-notes/corporate-profits-in-the-aftermath-of-covid-19-20230908.html.

Parisa, Zack, Eric Marland, Brent Sohngen, Gregg Marland, and Jennifer Jenkins. 2022. "The Time Value of Carbon Storage." Forest Policy and Economics 144 (November): 102840. https://doi.org/10.1016/j.forpol.2022.102840.

Partnership for Market Readiness. 2021. A Guide to Developing Domestic Carbon Crediting Mechanisms. World Bank. https://openknowledge.worldbank.org/handle/10986/35271.

Patnaik, Sanjay. 2023. How Carbon Permit Markets Can Lead Firms to Capture Surplus Rents: Empirical Evidence From the EU Emissions Trading Scheme (EU ETS). Brookings. https://www.brookings.edu/wp-content/uploads/2023/04/How-carbon-permit-markets-can-lead-firms-to-capture-surplus-rents-FINAL.pdf.

Partnership for Market Readiness. 2015. Options to Use Existing International Offset Programs in a Domestic Context. Technical Note No. 10. World Bank Partnership for Market Readiness. https://documents1.worldbank.org/curated/en/291491467999129585/pdf/99183-NWP-Box393189B-PUBLIC-add-series-name.pdf.

Probst, Benedict S., Malte Toetzke, Andreas Kontoleon, et al. 2024. "Systematic Assessment of the Achieved Emission Reductions of Carbon Crediting Projects." Nature Communications 15 (1): 9562. https://doi.org/10.1038/s41467-024-53645-z.

Race to Zero. 2022. Starting Line and Leadership Practices 3.0: Minimum Criteria Required for Participation in the Race to Zero Campaign. UNFCCC High Level Climate Champions. https://www.climatechampions.net/media/f2nkeckp/race-to-zero-criteria-30-4.pdf.

Race to Zero Expert Peer Review Group. 2022. Interpretation Guide. Version 2.0. UNFCCC High Level Climate Champions. https://climatechampions.unfccc.int/wp-content/uploads/2022/09/EPRG-interpretation-guide.pdf.

Regulation (EU) 2024/3012 of the European Parliament and of the Council of 27 November 2024 Establishing a Union Certification Framework for Permanent Carbon Removals, Carbon Farming and Carbon Storage in Products, Pub. L. No. PE/92/2024/REV/1, PE/92/2024/REV/1 PE/92/2024/REV/1 (2024). http://data.europa.eu/eli/reg/2024/3012/oj.

Rives, Karin. 2025. "With JPMorgan Gone, All Major US Banks Have Now Left Global Climate Alliance." S&P

Global Market Intelligence, January 7. https://www.spglobal.com/market-intelligence/en/news-insights/articles/2025/1/with-jpmorgan-gone-all-major-us-banks-have-now-left-global-climate-alliance-85961423.

Romm, Joseph, Stephen Lezak, and Amna Alshamsi. 2025. "Are Carbon Offsets Fixable?" Annual Review of Environment and Resources 50 (Volume 50, 2025): 649–80. https://doi.org/10.1146/annurev-environ-112823-064813.

Rosen, Amanda M. 2015. "The Wrong Solution at the Right Time: The Failure of the Kyoto Protocol on Climate Change." Politics & Policy 43 (1): 30–58. https://doi.org/10.1111/polp.12105.

Rydge, James. 2015. "Implementing Effective Carbon Pricing." Seizing the Global Opportunity: Partnerships for Better Growth and a Better Climate, New Climate Economy. https://newclimateeconomy.net/sites/default/files/2023-11/Implementing-Effective-Carbon-Pricing.pdf.

Sanders-DeMott, R., L. R. Hutyra, M. D. Hurteau, et al. 2025. "Ground-Truth: Can Forest Carbon Protocols Ensure High-Quality Credits?" Earth's Future 13 (5): e2024EF005414. https://doi.org/10.1029/2024EF005414.

Science-Based Targets initiative. 2023. SBTi Corporate Net Zero Standard, Version 1.1. Science-Based Targets initiative. https://sciencebasedtargets.org/net-zero.

Schlamadinger, B., N. Bird, T. Johns, et al. 2007. "A Synopsis of Land Use, Land-Use Change and Forestry (LULUCF) under the Kyoto Protocol and Marrakech Accords." Environmental Science & Policy, Options for including agriculture and forestry activities in a post-2012 international climate agreement, vol. 10 (4): 271–82. https://doi.org/10.1016/j.envsci.2006.11.002.

Schmalensee, Richard, and Robert N. Stavins. 2015. "Lessons Learned from Three Decades of Experience with Cap-and-Trade." Review of Environmental Economics and Policy RFF DP 15-51. https://media.rff.org/archive/files/document/file/RFF-DP-15-51.pdf#page=1.

Schneider, Lambert. 2007. Is the CDM Fulfilling Its Environmental and Sustainable Development Objectives? An Evaluation of the CDM and Options for Improvement. Institute for Applied Ecology. https://www.oeko.de/oekodoc/622/2007-162-en.pdf.

Schneider, Lambert. 2011. "Perverse Incentives under the CDM: An Evaluation of HFC-23 Destruction Projects." Climate Policy 11 (2): 851–64. https://doi.org/10.3763/cpol.2010.0096.

Schneider, Lambert, Michael Lazarus, and Anja Kollmuss. 2010. Industrial N2O Projects Under the CDM: Adipic Acid - A Case of Carbon Leakage? Stockholm Environment Institute.

Sengupta, Saptakee. 2025. "China Revives Its Carbon Credit Market: Price Swings & Future Outlook." CarbonCredits.Com, March 17. https://carboncredits.com/china-revives-its-carbon-credit-market-price-swings-future-outlook/.

Shabecoff, Philip. 1988. "U.S. Utility Planting 52 Million Trees." U.S. The New York Times, October 12. https://www.nytimes.com/1988/10/12/us/us-utility-planting-52-million-trees.html.

Smith, Stephen, and Joseph Swierzbinski. 2007. "Assessing the Performance of the UK Emissions Trading Scheme." Environmental and Resource Economics 37 (1): 131–58. https://doi.org/10.1007/s10640-007-9108-5.

Snyder, Katherine A. 2023. "Land-Based Mitigation Strategies and Their Implications for Local Communities in the Global South." Preprint, Lincoln Institute of Land Policy, September. https://www.lincolninst.edu/app/uploads/legacy-files/pubfiles/snyder_wp23ks1.pdf?publicationTitle=Land-Based_Mitigation_Strategies_and_Their_Implications_for_Local_Communities_in_the_Global_South&publicationType=WP&publicationSubtype=main&contentLanguage=English.

Spalding-Fecher, Randall, Amrita Narayan Achanta, Peter Erickson, et al. 2012. Assessing the Impact of the Clean Development Mechanism. High-Level Panel on the CDM Policy Dialogue. https://www.cdmpolicydialogue.org/research/1030_impact.pdf.

Stapp, Jared, Christoph Nolte, Matthew Potts, Matthias Baumann, Barbara Haya, and Van Butsic. 2023. "Little Evidence of Management Change in California's Forest Offset Program." Communications Earth & Environment 4 (1): 331. https://doi.org/10.1038/s43247-023-00984-2.

SustainCERT. 2024. "ICVCM and the First Carbon Credits with CCP-Labels." July. https://www.sustain-cert.com/news/what-you-need-to-know-about-the-icvcm-and-the-first-carbon-credits-with-core-carbon-principle-labels.
Sylvera. 2025. "CORSIA Carbon Credit Supply vs Demand: Will Airlines Be Ready for 2028 Compliance?" July 25. https://www.sylvera.com/blog/corsia-carbon-credit-supply-demand-airlines-compliance.
Szabo, Michael. 2010. "U.N. Panel Suspends Two More Carbon Emissions Auditors." Reuters (London), March 26. https://ukwin.org.uk/files/pdf/Reuters_10_CDM_auditors_suspended.pdf.
Tang, Yuzhi, Chao Yang, Haishan Wu, et al. 2025. "Tropical Forest Carbon Offsets Deliver Partial Gains amid Persistent Over-Crediting." Science 390 (6769): 182–87. https://doi.org/10.1126/science.adw4094.
Tarantino, Bill, Krista deBoer, and Ashley Quinn. 2025. "Climate and Carbon Litigation Trends." The Harvard Law School Forum on Corporate Governance, July 7. https://corpgov.law.harvard.edu/2025/07/07/climate-and-carbon-litigation-trends/.
TESTIMONY OF DR. JANET YELLEN CHAIR, COUNCIL OF ECONOMIC ADVISERS BEFORE THE HOUSE COMMERCE COMMITTEE ON THE ECONOMICS OF THE KYOTO PROTOCOL: Hearing before the Subcommittee on Energy and Power (1998). https://clintonwhitehouse4.archives.gov/WH/EOP/CEA/html/19980304.html.
The Economist. 2012. "Complete Disaster in the Making." September 15. https://www.economist.com/finance-and-economics/2012/09/15/complete-disaster-in-the-making.
The Economist. 2025. "The Remarkable Rise of 'Greenhushing.'" July 29. https://www.economist.com/business/2025/07/29/the-remarkable-rise-of-greenhushing.
The Nature Conservancy. 2009. Noel Kempff Mercado Climate Action Project: A Case Study in Reducing Emissions from Deforestation and Degradation. The Nature Conservancy.
Trencher, Gregory, Mathieu Blondeel, and Jusen Asuka. 2023. "Do All Roads Lead to Paris?" Climatic Change 176 (7): 83. https://doi.org/10.1007/s10584-023-03564-7.
Trexler, Mark, Derik Broekhoff, and Laura Kosloff. 2006. "A Statistically-Driven Approach to Offset-Based GHG Additionality Determinations: What Can We Learn?" Sustainable Development Law & Policy 6 (2).
Trouwloon, Danick, Charlotte Streck, Thiago Chagas, and Glenpherd Martinus. 2023. "Understanding the Use of Carbon Credits by Companies: A Review of the Defining Elements of Corporate Climate Claims." Global Challenges 7 (4): 2200158. https://doi.org/10.1002/gch2.202200158.
Truitt, Nathan, and Lynn Riley. 2025. A Trust For Permanence: Enabling a New Generation of Permanent Nature-Based Credits in the Voluntary Carbon Market. American Forest Foundation. https://www.forestfoundation.org/permanence-trust/.
United Nations High-Level Expert Group. 2022. Integrity Matters: Net Zero Commitments by Businesses, Financial Institutions, Cities and Regions. United Nations High-Level Expert Group on the Net Zero Emissions Commitments of Non-State Entities. https://www.un.org/sites/un2.un.org/files/high-level_expert_group_n7b.pdf.
United Nations Development Programme. 2023. UNDP's High-Integrity Carbon Markets Initiative. United Nations Development Programme. https://www.undp.org/publications/undps-high-integrity-carbon-markets-initiative.
United Nations Environment Programme. 2013. "UNEP Risø CDM/JI Pipeline Analysis and Database." UNEP Risø Centre, May 1. https://web.archive.org/web/20130530110144/http:/cdmpipeline.org/cdm-projects-type.htm.
United Nations Framework Convention on Climate Change. 2012. "CDM Insights - Intelligence about the CDM - October 2012." United Nations Climate Change, October 31. https://cdm.unfccc.int/Statistics/Public/archives/201210/index.html.
United Nations Framework Convention on Climate Change. 2013. Annual Report of the Joint Implementation Supervisory Committee to the Conference of the Parties Serving as the Meeting of the Parties to the Kyoto Protocol. UNFCCC. https://unfccc.int/resource/docs/2013/cmp9/eng/04.pdf.
United Nations Framework Convention on Climate Change. 2023a. "Microsoft: Carbon Negative Goal | Global." United Nations Climate Change. https://unfccc.int/climate-action/un-global-climate-action-awards/climate-

neutral-now/microsoft-carbon-negative-goal.
United Nations Framework Convention on Climate Change. 2023b. "Project Activities." UNFCCC, December 31. https://cdm.unfccc.int/Statistics/Public/CDMinsights/index.html.
United Nations Framework Convention on Climate Change. 2025a. Standard: Article 6.4 Activity Standard for Projects. A6.4-SBM015-A11. https://unfccc.int/sites/default/files/resource/A6.4-SBM016-A06.pdf.
United Nations Framework Convention on Climate Change. 2025b. Standard: Demonstration of Additionality in Mechanism Methodologies. A6.4-SBM015-A11. https://unfccc.int/sites/default/files/resource/A6.4-SBM015-A11.pdf.
United Nations Framework Convention on Climate Change. 2025c. Standard: Setting the Baseline in Mechanism Methodologies. A6.4-STAN-METH-004. https://unfccc.int/sites/default/files/resource/A6.4-STAN-METH-004.pdf.
United Nations Framework Convention on Climate Change. n.d.-a. "Approved Baseline and Monitoring Methodologies for Large Scale CDM Project Activities." United Nations Climate Change. Accessed January 16, 2026. https://cdm.unfccc.int/methodologies/PAmethodologies/approved.
United Nations Framework Convention on Climate Change. n.d.-b. "Article 6 of the Paris Agreement." United Nations Climate Change. Accessed April 24, 2026. https://unfccc.int/process-and-meetings/the-paris-agreement/article6.
United Nations Framework Convention on Climate Change. n.d.-c. "Issuance Certified Emission Reduction (CERs)." UNFCCC. Accessed January 16, 2026. https://cdm.unfccc.int/Issuance/cers_iss.html.
United Nations Framework Convention on Climate Change. n.d.-d. "The Paris Agreement Exhibit." United Nations Climate Change. Accessed April 24, 2026. https://unfccc.int/about-us/unfccc-archives/the-unfccc-archival-exhibition/the-paris-agreement-exhibit.
United Nations Framework Convention on Climate Change. n.d.-e. "What Is REDD+?" UNFCCC. Accessed January 16, 2026. https://unfccc.int/topics/land-use/workstreams/redd/what-is-redd.
Voluntary Carbon Markets Integrity Initiative. 2025a. Scope 3 Action Code of Practice. Voluntary Carbon Markets Integrity Initiative. https://vcmintegrity.org/scope-3-action/.
Voluntary Carbon Markets Integrity Initiative. 2025b. VCMI Claims Code of Practice, Version 3.1. Voluntary Carbon Markets Integrity Initiative. https://vcmintegrity.org/vcmi-claims-code-of-practice/.
Verra. 2025a. "A New Era for High-Integrity Cookstove Credits as Verra's Methodology Is Approved by ICVCM." Verra, March 7. https://verra.org/a-new-era-for-high-integrity-cookstove-credits-as-verras-methodology-is-approved-by-icvcm/.
Verra. 2025b. "Singapore, Gold Standard, and Verra Publish Article 6.2 Crediting Protocol." Verra, November 12. https://verra.org/singapore-gold-standard-and-verra-publish-article-6-2-crediting-protocol/.
Verra. n.d. "The VCS in Compliance Markets." Accessed March 13, 2026. https://verra.org/programs/verified-carbon-standard/vcs-in-compliance-markets/.
Warnecke, Carsten, Niklas Hohne, Ritika Tewari, Thomas Day, and Aki Kachi. 2018. Opportunities and Safeguards for Ambition Raising through Article 6: The Perspective of Countries Transferring Mitigation Outcomes. New Climate Institute. https://newclimate.org/2018/05/09/opportunities-and-safeguards-for-ambition-raising-through-article-6/.
Wawrzynowicz, Ingrid, Matthias Krey, and Ximena Samaniego. 2023. Assessing and Comparing Carbon Credit Rating Agencies. Perspectives Climate Group. https://carbonmarketwatch.org/publications/assessing-and-comparing-carbon-credit-rating-agencies/.
West, Thales A. P., Jan Börner, Erin O. Sills, and Andreas Kontoleon. 2020. "Overstated Carbon Emission Reductions from Voluntary REDD+ Projects in the Brazilian Amazon." Proceedings of the National Academy of Sciences 117 (39): 24188–94. https://doi.org/10.1073/pnas.2004334117.
Wetterberg, Klas, Jane Ellis, and Lambert Schneider. 2024. The Interplay between Voluntary and Compliance Carbon Markets: Implications for Environmental Integrity. OECD Environment Working Papers No. 244. Vol.

244. OECD Environment Working Papers. https://doi.org/10.1787/500198e1-en.
Wetterberg, Klas, Elisa Lanzi, and Natali Gómez. 2025. Exploring Governments' Efforts to Shape Carbon Credit Markets: Possible Actions to Enhance Integrity. OECD Environment Working Papers. 263rd ed. OECD Environment Working Papers. https://doi.org/10.1787/0bafe9af-en.
World Bank. 2025. "Carbon Pricing Dashboard." Carbon Pricing Dashboard, August 28. https://carbonpricingdashboard.worldbank.org.
World Bank and Carbon Markets Infrastructure Working Group. 2025. Technical Guidance Note on Ecosystem Governance for Carbon Markets Infrastructure: Assessment and Recommendations. Washington, DC: World Bank. https://doi.org/10.1596/43269.
World Economic Forum. 2023. The Voluntary Carbon Market: Climate Finance at an Inflection Point. World Economic Forum and Bain & Company. https://www3.weforum.org/docs/WEF_The_Voluntary_Carbon_Market_2023.pdf.

Appendix A: Types of projects

FORESTRY AND LAND USE

- Includes:
  - Afforestation-reforestation/revegetation
    - Establishes new forests or restores deforested/degraded areas through tree planting and revegetation
  - Avoided deforestation (project-based REDD+)
  - Improved forest management
    - Extends harvest rotations or improves forest health
  - Agroforestry
    - Integrates forest cover with agricultural land use
  - Blue carbon
    - Avoid emissions or remove carbon dioxide in marine and coastal environments by restoring, conserving, or managing ecosystems, including wetland, mangrove, and seagrass habitats

RENEWABLE ENERGY

- Includes:
  - Wind
  - Hydropower
  - Solar
  - Biomass
  - Biogas

CHEMICAL PROCESSES/INDUSTRIAL MANUFACTURING

- Reduces greenhouse gas emitted in industrial settings, whether those emissions are from direct production or utilization as chemical reagents.
- Includes:
  - Nitrous oxide destruction
  - Hydrofluorocarbon reclamation
  - Fugitive emissions capture and destruction
  - Carbon capture and storage (at a point source)

HOUSEHOLD/COMMUNITY DEVICES

- Focuses on energy demand at the level of individual households and communities, often in rural locations with limited infrastructure.
- Includes:
  - Cookstove distribution
  - Community biogas and biodigester infrastructure
  - Water purification device distribution
  - Community-scale renewable energy and energy efficiency projects

WASTE DISPOSAL

- Includes:
  - Landfill gas destruction or utilization
  - Composting credits

AGRICULTURE

- Focus on reducing emissions from agricultural activities in farmland and pasture
- Includes:
  - Livestock methane mitigation projects
    - E.g., farm-scale biodigesters
  - Sustainable land management projects on farmland and grasslands

ENERGY EFFICIENCY/FUEL SWITCHING

- Address greenhouse gas emissions at the source of demand either by increasing the efficient use of power and heat in industrial and residential settings or by changing fossil fuels used in power generation to fuels like biomass and natural gas that have less global warming impact

TRANSPORTATION

- Focus on increasing the efficiency of transportation by developing new mass transit or supporting electric vehicle adoption or human-powered transportation

ENGINEERED REMOVAL

- Includes
  - Direct air capture
  - Biochar production
    - Heating organic material in a low-carbon environment to create carbon-rich charcoal
  - Enhanced weathering
    - Spreading finely ground silicate rock to bind carbon
  - Bioenergy with carbon capture and storage

Glossary

TERMS

Additionality. The principle that a project's avoided emissions or removals would not have occurred without the financial incentive to sell carbon credits.

Buffer pool. A reserve of credits set aside at the program level to compensate for reversal events.

Climate mitigation. Actions taken to reduce the concentration of greenhouse gases in the atmosphere.

Crediting programs. Organizations that establish standards and procedures for quantifying, verifying, and issuing carbon credits.

Exclusive claims. The principle that a carbon credit represents a unique claim to a specific quantity of emissions reductions, ensuring that the same mitigation outcome cannot be claimed by more than one party.

Leakage. An increase in greenhouse gas emissions outside of a project's boundaries caused as an indirect result of the project's activities

Mitigation contributions. Carbon credits used to contribute to climate goals but not claimed as direct offsets against a specific entity's emissions.

Mitigation hierarchy. A framework that outlines mitigation priorities, often prioritizing reducing one's own emissions before turning carbon offsetting.

Offsetting. The practice of compensating for an entity's emissions by paying for reductions or removals elsewhere.

Overestimation. The crediting of more avoided emissions or removals than a project has actually achieved.

Registry. A system to track the issuance, ownership, and retirement of carbon credits.

Retirement. The permanent cancelation of a carbon credit that has been used as a mitigation contribution or offset, preventing it from being used again.

Supplementarity limit. A cap on the proportion of an entity's compliance obligation that can be met with carbon credits in a regulatory system.

ACRONYMS

ART – Architecture for REDD+ Transitions
ACR – American Carbon Registry
ACCU – Australian Carbon Credit Unit
CAR – Climate Action Reserve
CCPs – (ICVCM's) Core Carbon Principles
CDM – (Kyoto Protocol) Clean Development Mechanism
CER – (CDM) Certified Emissions Reduction
CORISA – (ICAO's) Carbon Offsetting and Reduction Scheme for International Aviation
CRCF – (EU's) Carbon Removal and Carbon Farming
ERU – (JI) Emissions Reduction Unit
ETS – Emissions trading system
GHG – Greenhouse gas
GS – Gold Standard
ICAO – International Civil Aviation Organization
ICVCM – Integrity Council for the Voluntary Carbon Market
ITMO – (Article 6.2) Internationally Transferred Mitigation Outcome
JI – (Kyoto Protocol) Joint Implementation
PACM – (Article 6.4) Paris Agreement Crediting Mechanism
REDD+ – Reducing Emissions from Deforestation and Forest Degradation
NDC – (Paris Agreement) Nationally Determined Contribution
SBTi – Science Based Targets initiative
TSVCM – Taskforce on Scaling Voluntary Carbon Markets
UNFCCC – United Nations Framework Convention on Climate Change
VCM – Voluntary carbon market
VCMI – Voluntary Carbon Markets Integrity Initiative
VCS – (Verra's) Verified Carbon Standard
WCC – (U.K.'s) Woodland Carbon Code

Endnotes

1 These are referred to as jurisdictional programs to reduce emissions from deforestation and degradation, or J-REDD programs (Calyx Global 2025).

2 From a physical science perspective, permanence is required "on climate-relevant timescales" (Arcusa and Lackner 2025). To physically offset fossil CO_2 emissions, for example, the effects of offsetting mitigation should persist for at least 1,000 years (Brunner et al. 2024), which for practical purposes is "permanent." However, debates persist about whether it is possible to credit less-than-permanent carbon storage based on the economic value of delaying climate damage (Atal and Sylvan 2025; Groom and Venmans 2023; Parisa et al. 2022), and whether, for practical and policy reasons, shorter durations (like 40 or 100 years) should be adopted.

3 Note ART only issues credits to J-REDD programs, not project-based credits.

4 For reference, the world emitted over 52 billion tons of CO_2e in 2023 (Crippa et al. 2024)

5 Note that these figures includes both jurisdictional and project-based credits, although project-based credits comprise a majority of the market.

6 See https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage/direct-air-capture

7 See https://www.iif.com/tsvcm

8 See https://carboncreditquality.org/

9 Some jurisdictions, such as Australia and Canada, use variations of baseline-and-credit systems rather than traditional cap-and-trade models. In baseline-and-credit systems entities are assigned emissions baselines, usually based on historical emissions or performance benchmarks. Entities that emit below their baselines generate performance credits, and entities that exceed their baselines are required to surrender performance credits, carbon credits, or payments.

10 The first compliance period for Oregon's ETS concludes in 2027. As of writing, no Climate Community Investment (CCI) nonprofits have been approved, and no CCI credits have been issued or surrendered (Department of Environmental Quality 2026).

11 Note this projection was made prior to the 2026 conflict in Iran. Fuel disruptions driven by the conflict could substantially curb demand.

12 This is because if a cap is set at 10% below BAU emissions, then the system is designed to achieve a 10% emissions reduction. However, if 8% of compliance obligations can be met with carbon credits, 80% of the 10% reduction could be achieved through carbon credit use. (This assumes a traditional over-the-cap approach to carbon credits, where carbon credits add to the total number of compliance instruments available).

13 See https://frontierclimate.com/progress and https://www.symbiosiscoalition.org/

14 See https://www.rockefellerfoundation.org/news/energy-transition-accelerator-advances-with-new-secretariat-expert-consultative-group/

15 See https://www.gov.br/mre/pt-br/canais_atendimento/imprensa/notas-a-imprensa/declaracao-sobre-a-coalizao-aberta-de-mercados-regulados-de-carbono

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