CARBONMARK

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Leveraging Blockchain for Scalable Climate Impact

March 2025

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Introduction

The Voluntary Carbon Market (VCM) faced challenges throughout 2024. Although retirement demand remained steady, the overall market contracted due to declining credit prices. The market value peaked at around $2 billion in 2022 but has remained subdued since because of persistent integrity concerns, negative media coverage, and economic pressures.

However, projections by MSCI suggest a recovery is likely, with the market potentially reaching **$35 billion by 2030** and up to **$250 billion by 2050**.

Strengthening market integrity is one of the most important keys to recovery. Efforts to do so are already underway. The Integrity Council for the Voluntary Carbon Market (ICVCM) is driving higher standards through the **Core Carbon Principles**, while project developers, independent rating agencies, and regulatory bodies continue refining methodologies to ensure credibility and quality. These improvements collectively lay the foundation for a more robust and trustworthy market.

Complementary to these advancements, **blockchain technology** is emerging as a key enabler of transparency, efficiency, and trust in carbon markets. By providing immutable records, real-time traceability, and automated verification mechanisms, blockchain technology can reinforce ongoing integrity initiatives while accelerating the velocity of the market itself. This report explores how blockchain-enabled digital innovations, including Carbonmark's platform, address key market challenges, integrate seamlessly with existing integrity efforts, and catalyze the VCM's growth through practical solutions already in play.

Executive Summary

Market Overview

Carbon markets are unique and complex. Carbon credits are largely unregulated, and both governance and liquidity remain fragmented. The proliferation of various standards, quality criteria, and economic pressures exacerbated the many challenges of 2024, with integrity concerns contributing to subdued growth. However, the market is showing early signs of recovery. Projections from MSCI suggest a **10% growth rate in 2025**, reaching up to **$40 billion by 2030** and up to **$250 billion by 2050**.

This growth is contingent on the market's ability to build trust among its key participants. Corporates must have confidence in the integrity of the credits they purchase, knowing they are sourced through credible intermediaries. Similarly, market players, who view climate change as an existential crisis, must trust that carbon markets can play a vital role in addressing this challenge.

Increasing transparency and efficiency across the market can help foster this trust. However, the current environment is challenging, with skepticism often being used to justify a conservative approach to carbon credits, limiting the exploration of innovative solutions that could address the deep-rooted trust issues within the market.

Blockchain technology has emerged as a powerful tool capable of reshaping the market's operations. Acting as the "connective tissue" between fragmented market components, blockchain can accelerate the development of a more tech-enabled market that strengthens trust through the concept of "trustlessness" – allowing transparent data to be accessed and verified by all market participants. Additionally, blockchain brings efficiencies for market users, by offering automation opportunities via smart contracts, and provides a solid framework for integrating **digital Monitoring, Reporting, and Verification (dMRV)** tools into credit issuance processes.

Beyond infrastructure, the carbon asset class itself is undergoing significant transformation. The shift toward **Carbon Dioxide Removal (CDR)** projects is gaining momentum, with companies like Microsoft leading the charge in purchasing CDR credits.

By 2040, renewable energy and REDD+ projects are expected to comprise less than 20% of the market, while nature-based solutions such as biochar and afforestation will become more prominent. This transition to high-impact, permanent removals aligns with the consensus that Net Zero goals are unattainable without scaling carbon removals. This represents a major growth opportunity for the market, and the opportunity to validate the role it has to play within climate finance.

As regulatory frameworks evolve—especially with the finalization of CORSIA and Article 6 at COP29—the market is at a pivotal moment heading into 2025. Companies like Apple, Amazon, and Unilever are placing greater emphasis on high-integrity removals, aligning with the Integrity Council for the Voluntary Carbon Market's (ICVCM) Core Carbon Principles (CCPs) to reinforce trust and credibility.

The VCM's Infrastructure & Blockchain's Role

Carbon registries are the front door to trust in the VCM, ensuring credit issuance and retirement integrity. However, inefficiencies in traditional carbon markets—manual verification, lack of transparency, and slow transaction speeds—underscore the need for innovation.

Blockchain technology is emerging as a catalyst for change, offering immutable ledgers, automated smart contracts, and real-time traceability to enhance carbon credit integrity. Tokenization and decentralized platforms are already demonstrating how digital infrastructure can accelerate credit issuance, reduce fraud, and streamline transactions.

Smart contracts enable automation of validation, verification, and retirement processes, reducing friction and eliminating intermediaries. **Automated Market Makers (AMMs)** further enhance liquidity and price transparency, fostering more efficient market participation.

Scaling the Voluntary Carbon Market

The VCM must **scale 15-fold by 2030 and 100-fold by 2050** to align with Paris Agreement goals. Blockchain solutions can support this scale by ensuring credit-level integrity, reducing costs, and preventing double-counting.

Emerging use cases include:

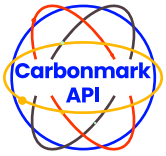
- **dMRV (digital Measurement, Reporting, and Verification)**: Real-time monitoring of emissions reductions, integrated with blockchain for increased transparency.
- **Carbon Credit Bridges**: Platforms such as Carbonmark, Toucan, and Moss tokenizing credits for seamless integration into digital markets.
- **Market Makers:** Klima Protocol driving liquidity and funding high-impact climate projects.

Carbonmark's Vision & Platform Offering

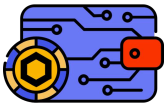
As a leading blockchain-enabled carbon marketplace, Carbonmark is at the forefront of driving transparency, efficiency, and accessibility within the VCM.

Key Offerings:

Carbonmark Marketplace: A peer-to-peer trading platform for verified carbon credits, ensuring traceability and efficiency.



Carbonmark API: Enabling seamless integration for corporate sustainability initiatives, digital wallets, and software developers.



Carbonmark Direct: A streamlined credit issuance and sales solution for project developers, supporting high-integrity methodologies like DACCS, BECCS, and enhanced rock weathering.

Looking Ahead

The VCM is entering a new era of innovation and collaboration. Blockchain technology presents a **scalable, transparent, and efficient solution** to existing market challenges, enabling a more robust and trustworthy carbon market. By integrating digital solutions thoughtfully, stakeholders can accelerate climate action and establish a high-integrity, scalable carbon market for the future.

In contrast, the supply of traditional (off-chain) carbon credits has surpassed 1.25 billion, with nearly 650 million retired. This reflects an ongoing trend in which the VCM is adapting to increasing scrutiny and rising demand for high-integrity credits, particularly as companies adopt more stringent climate targets.

1. Market Trends and Overview

1.1 Current Market Size

In 2024, the voluntary carbon market was valued at approximately USD 1.4 billion, according to a report by our partners at MSCI, indicating that the market continues to experience subdued growth since 2022.

Retirement volumes in the carbon credit market remained stable for the fourth consecutive year, totaling 162.6 million credits across the four major registries—a slight dip from 163.7 million in 2023. Shell led as the largest retiree, accounting for 9% of all retirements, followed by energy companies such as Eni (5.8 million), Engie (2.1 million), and Woodside (1.4 million).

Despite this, signs of renewed momentum are emerging. Allied Offsets, in its VCM 2024 Review, indicates that the number of companies retiring carbon credits increased from slightly over **6,000 in 2023** to over **6,500 in 2024**, marking a steady year-over-year rise. According to the Science Based Targets initiative (SBTi), over 10,000 businesses have set ambitious climate targets, bolstered by favorable policy shifts and positive market developments, which we will discuss further.

By the end of 2024, more than 6,000 carbon projects were registered across the 12 largest international crediting registries. These projects collectively issued 305 million metric tons of CO_2 equivalent ($MtCO_2e$) in 2024.

The continued development of Carbon Dioxide Removal (CDR) credits is a particularly bright spot in the market – according to MSCI, 2024 was a record year in which carbon removal projects received over **14 billion dollars in investments**, reflecting the sentiment that durable carbon removals have a critical role to play in helping society reach Net Zero, as well as reinforcing the carbon market's ability to scale and evolve to meet emerging corporate demand.

Blockchain technology is gaining space in the VCM. Since 2021, the blockchain-enabled carbon markets have taken a share, with over 26.8 million tokenized carbon credits circulating across Polygon, Ethereum, Base, and Celo. New tech solutions have transformed the industry, including AI-powered digital Measurement, Reporting, and Verification (dMRV) tools and cross-chain carbon credit interoperability protocols, enabling more accurate, scalable, and verifiable credit issuance.

1.2. Market Challenges

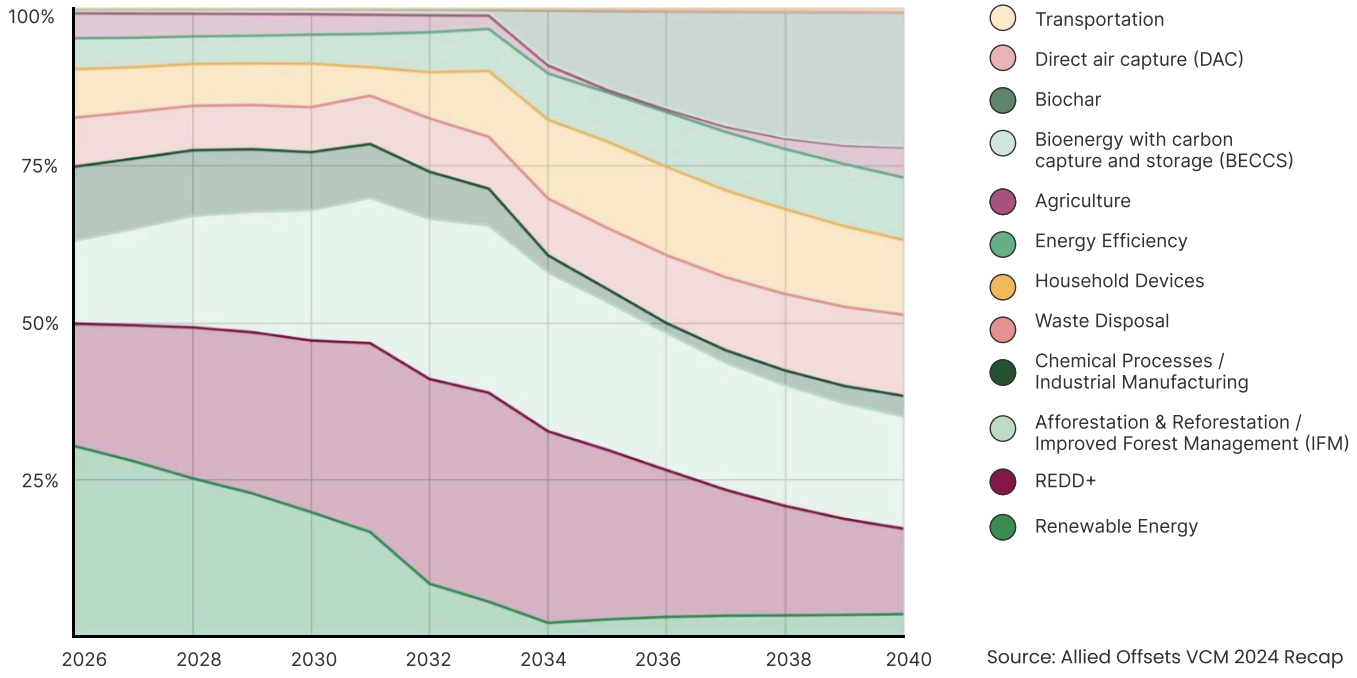
The VCM is currently experiencing a significant oversupply of credits, as new issuances exceed retirement demand, exerting downward pressure on prices. This oversupply has surpassed 3 billion credits. (AlliedOffsets)

As a result, lower-cost credits dominate transactions, stifling overall price growth and hindering the transition to high-integrity projects with greater additionality and permanence, which are usually technology- and capital-intensive. This situation presents severe challenges for project developers focused on higher-cost carbon credits, including carbon removal projects with long-duration sequestration, as they struggle to compete on pricing in what has become a buyer's market.

In 2024, pricing pressures led to a 20% decline in spot prices, bringing the average price per tonne to $4.80—a 32% drop since 2022. While carbon avoidance and mitigation credits continue to dominate total retirements (70% in 2024), a gradual shift toward carbon removal credits has begun to emerge. Engineered removals, in particular, achieved notable price differentiation, exceeding $100 per tonne.

According to AlliedOffsets, average carbon credit prices are expected to remain below $10 per tonne until 2030, gradually rising to **$30 by 2035**. EY projects even higher prices, forecasting a range of **$75–$125 per tonne by 2035**, driven by rising quality standards and increasing demand.

VCM as we expect it to evolve over time



Source: Allied Offsets VCM 2024 Recap

A persistent challenge in the market is the weak correlation between credit quality and pricing —high-quality projects are often undervalued despite despite their higher development costs. This misalignment hampers the market's transition toward integrity-driven pricing. However, the growing demand for high-quality credits presents an opportunity for change. By increasing transparency, reinforcing strong standards, and fostering innovation, the market can better align credit pricing with impact, encouraging investment in projects that support global net-zero goals as well as localised co-benefits for communities, biodiversity and the economy.

1.3 Sector Market Trends

The VCM is undergoing a shift in focus toward CDR, particularly through carbon-removing nature-based solutions (NBS), such as restorative agriculture, and emerging engineering technologies like direct air capture (DAC).

In 2024, CDR remained a niche yet growing market segment. Microsoft is currently leading the way, purchasing over 50% of all historic CDR credits, with 57% of total CDR purchases for the year. Bioenergy with Carbon Capture and Storage (BECCS) dominates the sector, accounting for 82% of total volumes. A notable milestone was reached in December 2024 when Terradot signed agreements to supply 290,000 tonnes of CDR to Google and Frontier between 2025 and 2030. Despite these advancements, removals represented only 9% of retired credits in 2024, highlighting the need for further investment and scaling of CDR solutions.

By 2040, AlliedOffsets forecasts that renewable energy and REDD+ projects will comprise less than 20% of the market—down from 50% today. In contrast, NBS removal projects, such as biochar and Afforestation, Reforestation, and Revegetation (ARR), are expected to attract increasing interest from buyers.

1.4. Market Outlook for 2025

Estimates of the voluntary carbon market's (VCM) growth potential remain ambitious— up to **$40 billion by 2030** and up to **$250 billion by 2050** —due to the growing demand for high-integrity credits. Although market conditions have been challenging in recent years, several developments support long-term growth. These include the transition of CORSIA from the Pilot Phase to Phase 1, progress made at COP29 on the implementation of Article 6, and the fact that we are inching closer to 2030, when Net Zero target commitments and requirements to offset residual emissions will become more pressing.

Market Momentum in 2025

The year 2025 is poised to be a turning point for the VCM, driven by regulatory and corporate actions:

- **Regulatory momentum has accelerated**, with the EU and Singapore introducing hybrid compliance-voluntary carbon frameworks, bridging the gap between voluntary and mandatory carbon markets. Additionally, progress on Article 6 of the Paris Agreement at COP29 is expected to enhance international carbon trading mechanisms, allowing governments and companies to trade high-integrity credits across borders under a unified regulatory framework.

- **Corporate sustainability leaders**, including Apple, Amazon, and Unilever, have **intensified their focus on carbon removal strategies**, signaling increased demand for premium, high-integrity credits.

- **Emerging standards**, such as the **ICVCM's Core Carbon Principles (CCPs)**, are gaining widespread adoption, strengthening market integrity and boosting buyer confidence. Meanwhile, **CORSIA** is reinforcing demand for credible carbon offsets within the aviation industry, requiring airlines to purchase verified credits to meet their emission reduction obligations.

Scaling the Voluntary Carbon Market

The VCM is poised for significant expansion to align with the goals of the Paris Agreement. The **Taskforce on Scaling Voluntary Carbon Markets (TSVCM)**, recognizing the essential role of the VCM in global climate strategies, estimates that these markets must grow 15-fold by 2030 and an ambitious 100-fold by 2050, if they are to play a key role in fostering a sustainable, low-carbon future. In its November 2020 Consultation Document, and its January 2021 Phase II Report, the TSVCM identified key challenges that must be resolved to unlock this growth.

Key Takeaways

The outlook for 2025 reflects cautious optimism. While challenges remain, regulatory advancements, corporate leadership, and the adoption of stringent integrity standards are laying the foundation for sustained market recovery and growth, driven by the integration of blockchain technology. As stakeholders prioritize high-quality credits and invest in innovative solutions, the VCM is well-positioned to play a pivotal role in global net-zero strategies.

This convergence of innovation, blending top-down strategic initiatives with bottom-up technological advancements, promises to enhance the VCM's capacity for transparency and reliability. Ultimately, this will steer the market toward a future where it not only excels in operational efficiency but also plays a crucial role in advancing global sustainability goals.

The TSVCM's proposals are (at their core) calls to improve integrity and trust in the VCM – 5 years later, these proposals remain as relevant as ever.

However, the blockchain-enabled market clearly demonstrates the work that is being done to address a number of the concerns highlighted by the TSVCM. Carbonmak, therefore, makes the case for deeper integration between the VCM's traditional systems and those that will be required in the future to power trusted, high-integrity carbon markets.

2. The VCM's Infrastructure

Carbon registries are the foundation of trust in the VCM. As the central infrastructure ensuring integrity, transparency, and accountability, registries support every transaction, from credit issuance to transfer and retirement. Without them, the market simply cannot function.

Since the establishment of the Clean Development Mechanism (CDM) Registry in 2005, registries have evolved into sophisticated systems that often play a dual role of governing the flow of carbon credits, as well as ensuring that reductions or removals are real, measurable, and verifiable through the work they do as Standards Bodies. Their responsibility extends beyond individual projects: registries collectively shape the market's credibility and influence its capacity for growth.

In lieu of regulation and clear market rules, registries serve as de facto gatekeepers to the market, a critical question arises: **to what extent should they facilitate innovation that enhances market efficiency, integrity, and scalability?** The decisions they make today will shape the trajectory of the VCM in the years ahead.

2.1 How traditional carbon registries work

Carbon standards and registries, such as Verra and Gold Standard, operate as authoritative databases, managing carbon credits issued under their respective standards. Their stringent validation and verification protocols of the carbon standards ensure the credibility of credits, while their tracking mechanisms provide essential market transparency.

The role of registries extends beyond credit management—**they establish the rules** that shape project methodologies, reporting requirements, and data accessibility. As a result, registries hold significant influence over market accessibility and innovation.

The process of issuing carbon credits involves multiple stakeholders, including project developers, independent auditors, and regulatory bodies. Trust in this market relies on accurate data and rigorous validation to maintain market integrity. Any erosion of trust—whether due to inconsistent methodologies, opacity, or fraud—can have widespread consequences. Ripple effects are still felt today from turbulence in the VCM in 2023, driven by scrutiny over REDD+ projects, underscored how critical registries are in maintaining confidence.

Strengthening this trust requires ongoing improvements across the entire ecosystem, with registries playing a pivotal role in ensuring transparency, consistency, and accountability. As gatekeepers, they have the power to facilitate innovation—or to restrict it.

Despite their central role, registries face mounting challenges as the market grows in complexity:

Monitoring Efficiency:
Manual reporting and periodic verification introduce delays and inefficiencies, making real-time tracking difficult.

Evolving Methodologies:
Scientific advancements and technological innovations are outpacing some registry frameworks, leading to inconsistencies in credit valuation.

Trust and Transparency:
Limited access to Measurement, Reporting, and Verification (MRV) data places a heavy burden on buyers to conduct due diligence, increasing market friction.

2.2 Strengthening Trust and Integrity in the VCM

Recognizing these challenges, market participants have taken proactive steps to improve verification, transparency, and regulatory alignment. All of these activities aim to foster trust in the VCM.

Improved verification and monitoring

There has been a concerted effort to enhance verification and monitoring processes. This includes more rigorous independent audits and the use of advanced technology like satellite imagery to track conservation efforts and emissions reductions accurately.

Revised methodologies and standards

Carbon standards organizations have been updating their methodologies and guidelines to prevent overestimating carbon savings. This includes revising how carbon credits are calculated and incorporating more accurate data on emissions reductions. Verra's new VM0047 methodology for Afforestation, Reforestation, and Revegetation (ARR), for example, relies on remote sensing to establish a project's baselines.

Public and stakeholder engagement

Increasing public awareness and stakeholder engagement ensures that projects are scrutinized more closely, fostering a culture of accountability. This engagement also encourages adopting best practices in project development and carbon credit issuance. Having engaged hundreds of organizations to develop the Core Carbon Principles (CCPs), the Integrity Council for the Voluntary Carbon Market (ICVCM) is an example of a pioneer in this effort.

Policy reforms and compliance measures

Regulatory bodies have been working to reform policies to close loopholes allowing exploitation within the carbon credit system. This includes stricter compliance measures and penalties for non-compliance. Rating agency Sylvera, for example, has partnered with the Government of Singapore to enhance data, audit, and risk assessment methods—a key step toward credit interchangeability between the compliance and voluntary carbon markets.

Several other countries have initiated similar partnerships aimed at strengthening their carbon credit systems:

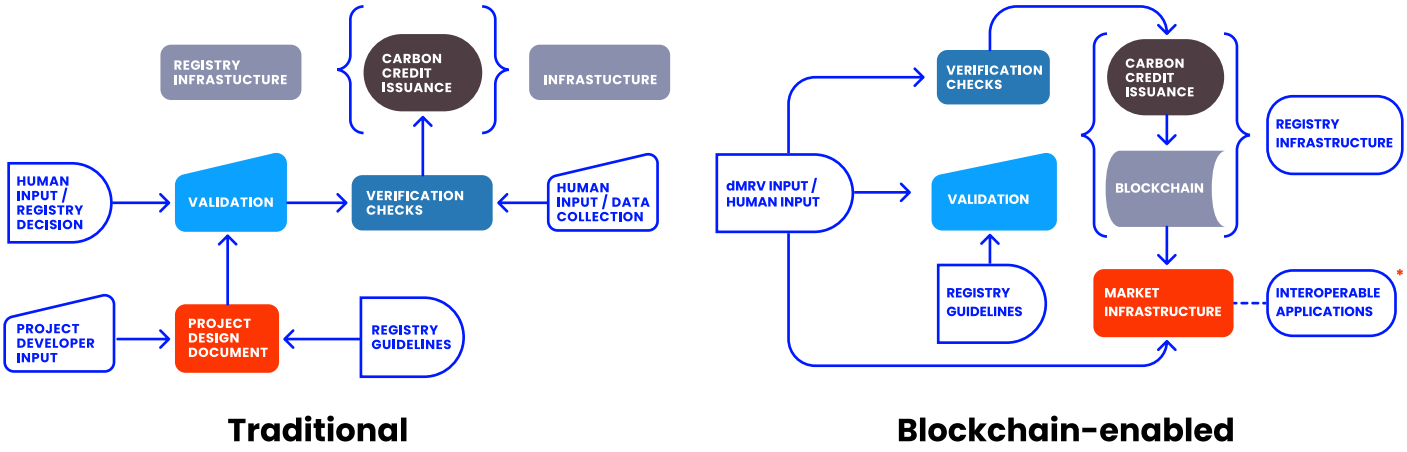
- **United States:** In May 2024, the Biden administration introduced a Voluntary Carbon Markets Joint Policy Statement and Principles aimed at enhancing market transparency, reducing greenwashing risks, and ensuring credits reflect real emissions reductions.

- **European Union**: Following COP29, the EU is implementing Article 6.4 of the Paris Agreement, centralizing its carbon market to uphold environmental integrity and support least developed countries in carbon market participation.

- **Latin America:** Latin American countries are increasingly integrating carbon pricing instruments and Article 6 mechanisms into their regulatory frameworks and policy documents, including laws, decrees, strategies, ministerial agreements, and national policies. For example, Ecuador is developing a national framework for Internationally Transferred Mitigation Outcomes (ITMOs), while Panama is crafting a roadmap to establish its carbon market. Meanwhile, Chile and Argentina have devised strategies to implement carbon pricing instruments and manage cooperative approaches. Across the region, 287 projects have applied to transition to the Paris Agreement Crediting Mechanism (PACM), enabling the continuation of emission reduction initiatives in sectors such as renewable energy and energy efficiency. Brazil is at the forefront of this transition, accounting for 43% of applications submitted as of November 2024.

These partnerships reflect a broader trend in 2024 towards **greater collaboration between governments and organizations** to enhance the integrity and functionality of carbon credit systems globally. Registries, as the central player, are expected to adapt to evolving market demands while maintaining their foundational role in ensuring credibility.

2.3 Blockchain as a catalyst for Innovation



How Blockchain Works and the Role of Smart Contracts in the VCM

Blockchain technology operates as a decentralized, immutable ledger that records transactions across multiple nodes in a network. This design ensures that once data is recorded, it cannot be altered retroactively without consensus from the entire network, making blockchain highly secure and tamper-proof.

One of blockchain's standout features is its transparency. All transactions are visible to participants on the network, fostering trust and accountability. The decentralized nature of blockchain eliminates the need for intermediaries, reducing costs and increasing efficiency.

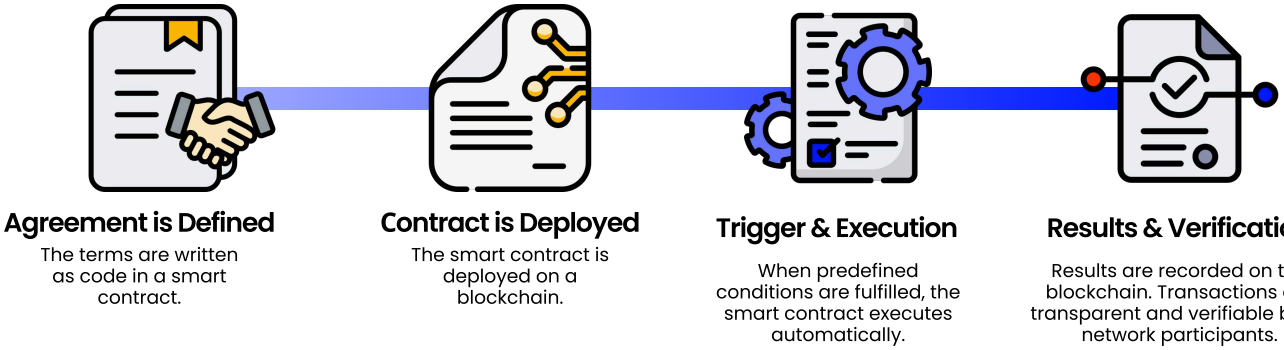
For carbon markets, this means **the entire lifecycle of a carbon credit**—from issuance to retirement—**can be traced with unparalleled clarity**, ensuring authenticity and reducing the risk of fraud. This fully traceable chain of custody ensures a compliant offset claims process. Additionally, the data availability of blockchain provides compliance market stakeholders with increased assurance that the credits they purchase satisfy their requirements and have not been double-counted.

A critical innovation within blockchain technology is the use of smart contracts —self-executing contracts where the terms of the agreement are directly written into lines of code.

Smart contracts automatically enforce agreements when predefined conditions are met, eliminating the need for manual oversight or third-party intervention. In carbon markets, smart contracts can automate the verification and retirement of carbon credits, ensuring a more efficient and reliable process.

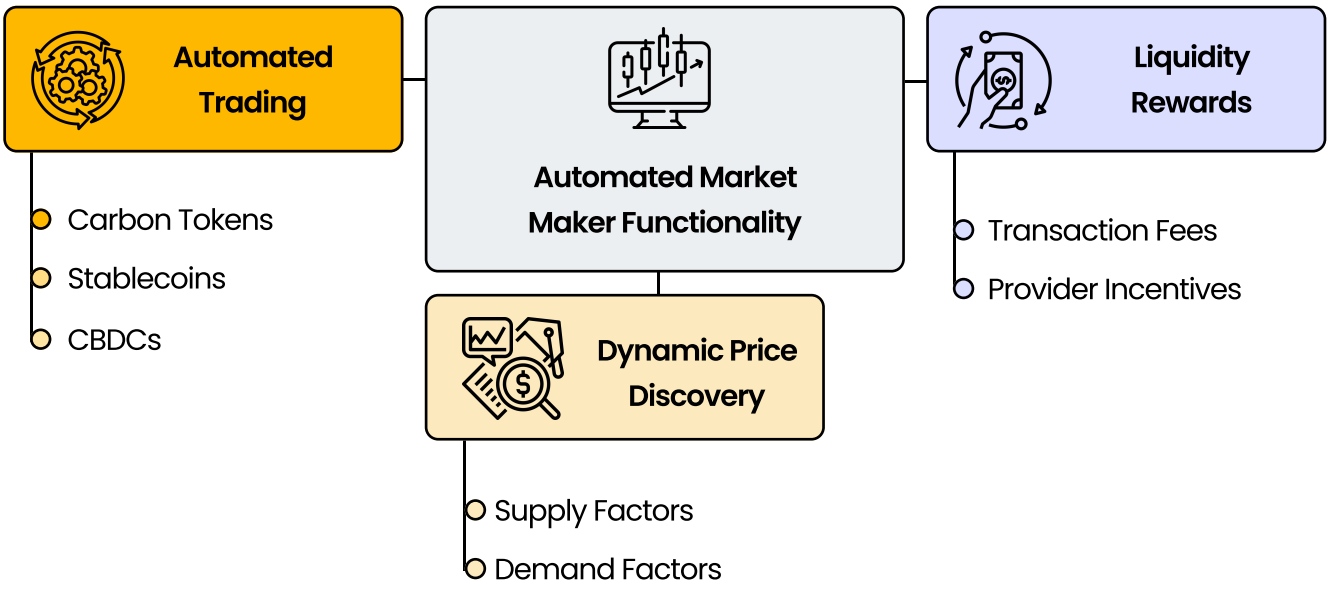
Smart Contracts: what can they accomplish in carbon markets?

Smart contracts bring automation and transparency to carbon markets, enabling seamless credit retirement, fractional transactions, and integration with dMRV systems. By leveraging blockchain infrastructure, smart contracts securely transfer carbon credits from their host registry to blockchain infrastructure, ensuring that key on-chain events—such as credit retirements and transfers—are automatically recorded and shared with carbon registries.



Smart Contract Use-Case: Automated Market Makers (AMMs) in Carbon Trading

Smart contracts power a range of blockchain-enabled technologies. **Automated Market Makers (AMMs)** are a leading example of smart contract technology applied in carbon markets to date. AMMs facilitate automated trading, enhance liquidity development, and enable real-time asset pricing, ultimately improving market efficiency. The transaction fees are transparently listed, and the AMM itself serves as the counterparty with a buyer or seller, which minimizes the risk of value extraction via intermediaries.



AMM Smart Contracts Enable:

- **Automated Trading** – Users have the ability to buy or sell carbon credits, with instant settlement and no wait time for delivery of the carbon asset.
- **Liquidity Rewards** – Incentives for liquidity providers through transaction fees.
- **Real-time Pricing** – Transparent pricing based on real-time market transactions gives certainty to buyers and sellers, and can act as reference pricing for the broader market.
- **Transparency** – All fees, transactions and market activity is publicly available for all market stakeholders which can help bring confidence to the market.
- **Equal Access** – AMMs can allow any entity holding carbon credits or capital to access the market, meaning market participants who may historically be dependent on intermediaries to transact, can do so themselves.

AMMs demonstrate the value that smart contracts can bring to the carbon markets, by bringing greater transparency and accessibility to the market, and reducing transaction costs and times.

Blockchain-enabled carbon registries

At a fundamental level, the blockchain's immutable ledger can lead to a step change in how markets function. It provides a transparent and tamper-proof record of transactions, which significantly enhances accountability. It can reduce risks and friction associated with credentialed access to siloed databases. Further, the ability for interoperable systems to be developed through smart contract technologies can further increase the overall velocity of a market as friction between disparate systems is reduced. The benefits of blockchain technologies – and the tokenization of so-called **Real World Assets (RWAs)** – are being explored across many different types of securities and commodities markets.

Given that carbon credits are themselves digitally native commodities – and the representation of them as a token on the blockchain is neither technically more challenging, nor any more costly, than representing them as an asset in a database – we suggest that blockchain technologies and the carbon markets are primed to work hand-in-hand with one another. Further, carbon registries, in particular, are well-placed to facilitate the adoption of blockchain technologies, either by themselves transitioning to new systems, or by allowing market participants to augment their market operations by leveraging blockchain technologies.

If registries choose to integrate digital solutions thoughtfully, they could help move the market forward while keeping their position as the ultimate source of truth, enabling more dynamic and efficient market interactions. Digital MRV, automated verification, and secure on-chain tracking could facilitate real-time data transparency, reducing friction across the market.

2.4 Toward a blockchain-enabled carbon market

By early 2025, blockchains supporting tokenized assets held a total value locked (TVL) of $120 billion, with Ethereum leading at $66.1 billion. The tokenization of real-world assets (RWAs), including commodities, has gained traction, growing from $8 billion in 2023 to $14 billion by January 2025—a reflection of broader adoption trends.

Projections suggest that the RWA market could expand significantly, potentially reaching between $2 trillion and $30 trillion by 2030. Given the low-technical complexity and transition costs of "tokenizing" carbon credits, integrating blockchain technology with carbon credits is a feasible path forward for the market.

Indeed, it is perhaps more straightforward for the carbon markets to transition to the blockchain, than applications areas where significant steps forward in tokenization have already taken place, including applications in commodities, intellectual property, and securities.

The rate of blockchain adoption within carbon markets, of course, remains to be seen—there is ongoing caution regarding viewing technology as a silver bullet for market issues. In 2022, many of the leading carbon registries outright banned tokenization, and have not changed their stance. In November 2023, Gold Standard released a series of reports examining the role digital solutions might play in the future of carbon markets, acknowledging that blockchain technology can lead to a step change in certain market areas while delivering only marginal improvements in others.

Despite a number of carbon registries not yet adopting blockchain support frameworks (e.g. Verra, Gold Standard, and ACR), various projects have been exploring blockchain applications across the carbon market value chain for a number of years. The following sections outline key use cases and highlight examples of ongoing initiatives.

2.5 Challenges for Blockchain Adoption

While the future of the VCM with blockchain technology appears promising, several challenges must be addressed by blockchain proponents to gain support and market acceptance for these solutions to be more holistically integrated into the market.

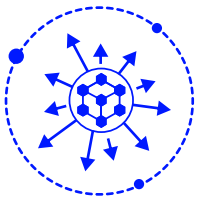
Scaling Requires Speed and Coordination

Carbon markets must scale rapidly to align with global decarbonization goals, but achieving this requires unprecedented coordination among diverse stakeholders, including regulators, corporations, policymakers, and local communities. The fragmented and uncoordinated nature of carbon markets makes it difficult for blockchain proponents to identify key market gatekeepers and decision-makers, limiting their ability to effectively advocate for their solutions.

Trust, Credibility, and Real-World Impact

Public skepticism surrounding carbon markets stems from concerns over greenwashing and credibility. Greater transparency and verification are essential to build trust. While blockchain solutions can support these objectives, their association with speculative and sometimes fraudulent cryptocurrency activities is seen as a potential risk to market integrity. Many fear that deeper blockchain integration could exacerbate existing trust issues rather than resolve them.

Additionally, critics argue that blockchain-based solutions and the communities that support them often prioritize digital hype over tangible climate impact. To gain broader acceptance, blockchain projects must shift the focus from theoretical benefits to measurable, verifiable emissions reductions and regenerative practices rather than flashy technology or intangible promises.



Complexity and Education Gaps

Blockchain technologies remain highly complex and are often misconstrued as being synonymous with disruptive decentralization, disintermediation, and ideological agendas. The “tech-first” approach taken by many blockchain advocates can create significant education and ideological gaps among key players in the carbon market ecosystem. To bridge this divide, blockchain proponents must improve outreach and communication to foster collaboration with traditional carbon market participants while avoiding insularity and elitism.

Regulatory Uncertainty and Market Access Barriers

The lack of clear regulations for digital assets makes it difficult for blockchain proponents to gain the trust of market gatekeepers, who require assurances that appropriate protections are in place to preserve market integrity. Furthermore, the absence of regulations in voluntary carbon markets has de facto positioned carbon registries as gatekeepers, allowing them to determine who has market access and who does not. This has largely excluded new entrants from participating in the market.

In the absence of clear regulations, blockchain advocates must rely on carbon registries to establish defined frameworks and Terms of Service that allow new market participants to engage with the market. To secure buy-in from registries, blockchain proponents must demonstrate real-world impact, address concerns surrounding trust and integrity, and shift the narrative from hype to practical benefits through clear and effective communication.

3. The Opportunity for Blockchain

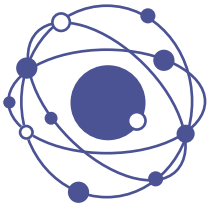
Throughout 2025, the market expects to see further innovation across all areas of the VCM — from top-level institutional working groups aiming to bring clarity around credit integrity to bottom-up projects leveraging state-of-the-art technology that can bolster the market's efficiency and trust.

3.1 Supporting the Market's Credit-level Integrity

In its January 2021 Phase II Report, the TSVCM proposed numerous mechanisms to build credit-level integrity within the VCM. Of particular note are calls to improve the accuracy and frequency of MRV, as well as risk, leakage, and impact assessment and mitigation measures. Blockchain technology opens up a range of benefits and opportunities that can be leveraged in support of achieving the action items set out by the TSVCM.

Automated validation and verification

Blockchain revolutionizes the development and enforcement of carbon standards, particularly in project development and monitoring. Utilizing distributed ledger technology, validation and verification processes become automated and auditable, enhancing the frequency and reliability of assessments. This automation leverages Internet of Things devices and remote sensing to enable dMRV, tying data feeds directly into the carbon credit metadata and ensuring a more thorough and accurate evaluation of carbon projects. All this can bring more confidence to buyers, which can ultimately support higher carbon pricing.

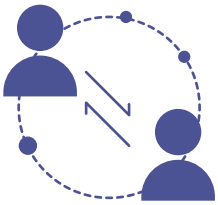


Real-time, transparent tracking, tracing and settlement

Blockchain-enabled carbon registries enable real-time and transparent tracking of transactions and retirements, enabling all market participants to view and verify transactions as they happen. Such transparency ensures that every carbon credit's journey—from issuance to retirement—is traceable and transparent, building trust and credibility. Further, the immediate execution of transparently priced carbon credit transactions and the immutable, public verification of market operations help eliminate fraud and streamline compliance with regulatory and voluntary market standards.

Lower costs, faster onboarding

The integration of blockchain significantly reduces account management costs and streamlines the onboarding process, making the carbon market more accessible to a wider range of participants. By enabling direct peer-to-peer transactions, the need for intermediaries is reduced, thereby reducing transaction costs.



Double-counting prevention

Smart contracts and tokenized assets on blockchain networks address double-counting issues. Immutable ledgers ensure that carbon credits are retired transparently, with instant retirement certificates automatically issued and publicly verified. A recent COP29 panel hosted by Biosphere3 explored how advanced technologies, particularly blockchain and artificial intelligence (AI), provide innovative solutions to this challenge.

Blockchain provides a technology layer that can integrate and surface the work thatis already being done by many organizations that are aiming to foster a high-integrity, trusted VCM. In the following section we outline how industry players are innovating in the VCM, making strides in addressing the credit-level integrity issues that the TSVCM has identified as crucial to unlocking growth.

3.2 A Step Change in Carbon Market Infrastructure

The five key action areas identified by the TSVCM that are required to spur the VCM's growth are readily addressed, integrated, and realized by blockchain-enabled carbon markets:

I **Establishing the CCPs**
The Core Carbon Principles (CCPs) are ten fundamental, science-based principles for identifying high-quality carbon credits that create real, verifiable climate impact. Developed by the Integrity Council for the Voluntary Carbon Market (ICVCM) with input from hundreds of organizations, they set out threshold quality criteria to which a carbon credit and the supporting standards and methodologies should adhere. Hosting these on a decentralized blockchain database ensures transparency, auditability, and immutability aligning to the VCM's fundamental principles.

II **Exchange-traded core carbon reference contracts**
In the traditional VCM, there are a limited number of liquid reference contracts with a reliable price signal in real-time. When tokenized, pooled, and deployed on smart-contract enabled infrastructure such as AMMs, blockchain-enabled carbon credits provide instant, real-time price discovery. For example, Carbonmark's Marketplace leverages underlying AMMs on Polygon to provide a publicly accessible carbon pricing dashboard.

III **Infrastructure: Building with Carbon Legos**
As an analogue to the 'Money Legos' concept in the decentralized finance (DeFi) ecosystem, blockchain enables interoperability between deployed applications and tokens. It allows different protocols, systems, and assets to communicate and integrate with one another, to validate new technological approaches that are designed to rapidly scale and achieve increased throughput of carbon credits through the market. The inherent interoperability of blockchain solutions can allow entire systems (e.g. carbon registries and marketplaces) to integrate with one another to more efficiently distribute carbon credits to market stakeholders.

IV

Offset Legitimacy

The TSVCM calls for principles to establish the legitimacy of offsets and the claims associated with them. Public blockchains not only enable these principles to be encoded but also provide complete transparency and traceability of carbon credits, ensuring that any related claims can be instantly audited by examining the retirement events, and the underlying data of the credits that have been retired.

V

Demand signaling

The transparency afforded by blockchain enhances the availability of key market information, including carbon credit volume and pricing data. Combined with the quality of linking credit liquidity across formerly isolated and siloed credit types and standards, blockchain can thus help drive the development of more liquid markets with clearer demand signaling.

Furthermore, public blockchains' open-source data and infrastructure enable the emergence of dynamic applications and data layers that significantly enhance user experience and make it easier for businesses and individuals to drive positive climate impact by understanding the available supply of carbon, its price, and the ability to immediately source it. Reducing barriers to entry on the demand-side of the market can underpin confidence of suppliers that their credits will efficiently find a route to market, and incentivise further investment into high-impact climate projects.

By leveraging blockchain at every level of the VCM's value chain, existing systems, and mechanisms are enhanced, paving the way for the market to scale. It is in this context that Carbonmark seeks to fulfill its vision of becoming the seamless interface that facilitates the flow of value and information across the market's disparate systems.

4. Case Studies: What's on the market today

The blockchain-enabled market has seen the development of transparent and efficient infrastructure rails, marketplaces, and on-chain retirement applications. It has also become increasingly important to allocate capital to forward-fund new carbon projects, paving the way for the issuance of increased volumes of blockchain-native carbon credits.

4.1. Interoperable registries

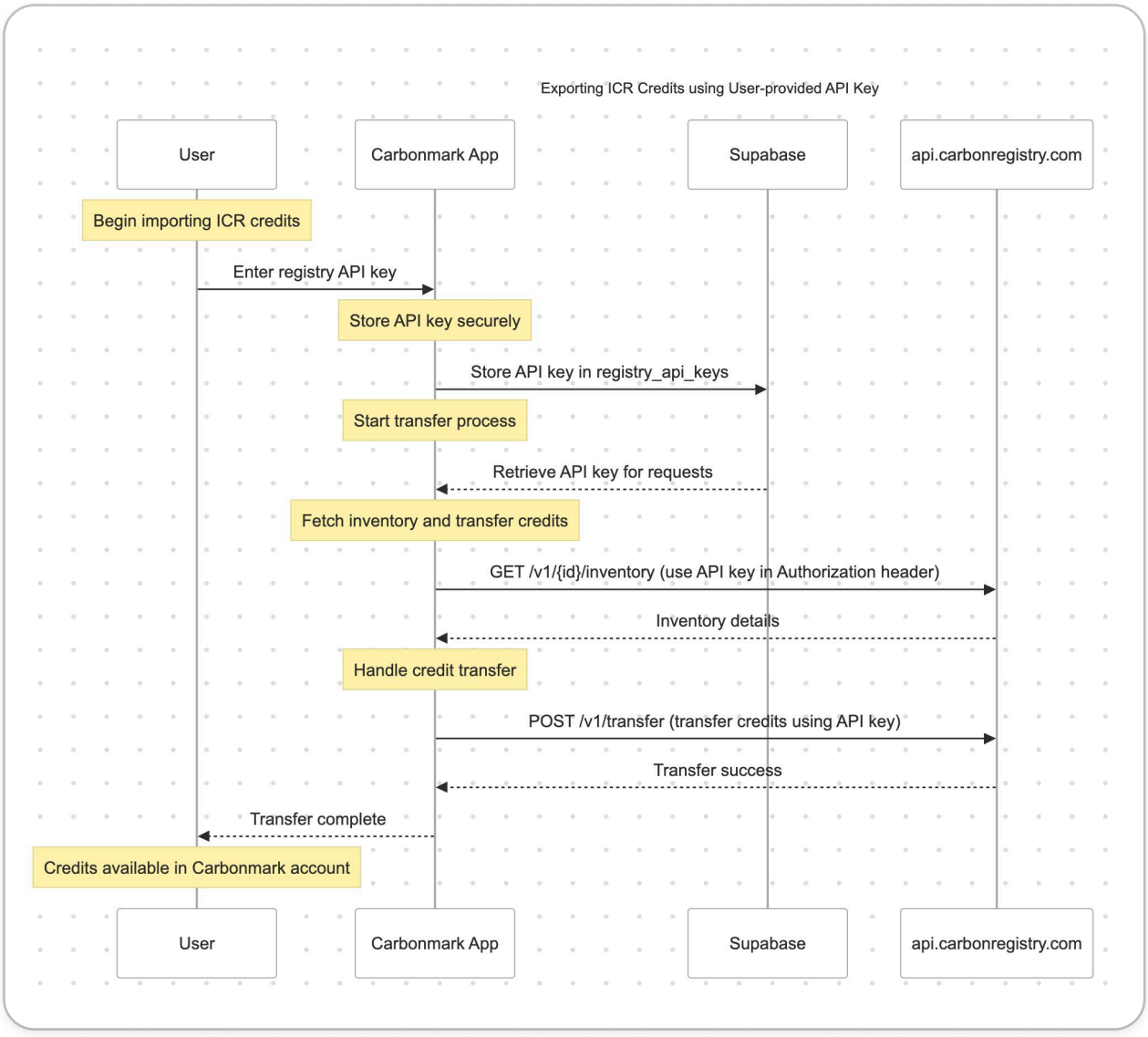
This section explores how some registries—Puro.earth, International Carbon Registry (ICR), and EcoRegistry—are leveraging blockchain technology to streamline the issuance, trading, and verification of carbon credits. These registries are pioneering new approaches to building trust and expanding market participation, ultimately supporting the credibility and scalability of carbon markets.

Puro.earth

Puro.earth certifies suppliers based on the Puro Standard. Removal is independently verified, and CO2 Removal Certificates (CORCs) are issued through the Puro Registry. CORCs require at least 100 years of permanence. While Puro.earth is not fully blockchain-based, it does support connections to blockchain as part of its broader technical infrastructure for specific applications. This interoperability supports the seamless integration with other platforms, including Carbonmark, enabling efficient and trustworthy carbon credit trading.

International Carbon Registry (ICR)

ICR has initiated issuing its credits directly onto the Polygon blockchain in a standard token format (ERC-1155). This minimizes the trust users must have in ICR's credit management system since the system's behavior is publicly verifiable. Issuing directly on Polygon enables ICR to interoperate natively with the most active blockchain-based carbon ecosystem. Its first blockchain-native credits have already been listed on the Carbonmark marketplace, with additional work underway to standardize data and processes. Apart from that, project developers can easily import and export credits directly between ICR and the Carbonmark platform.

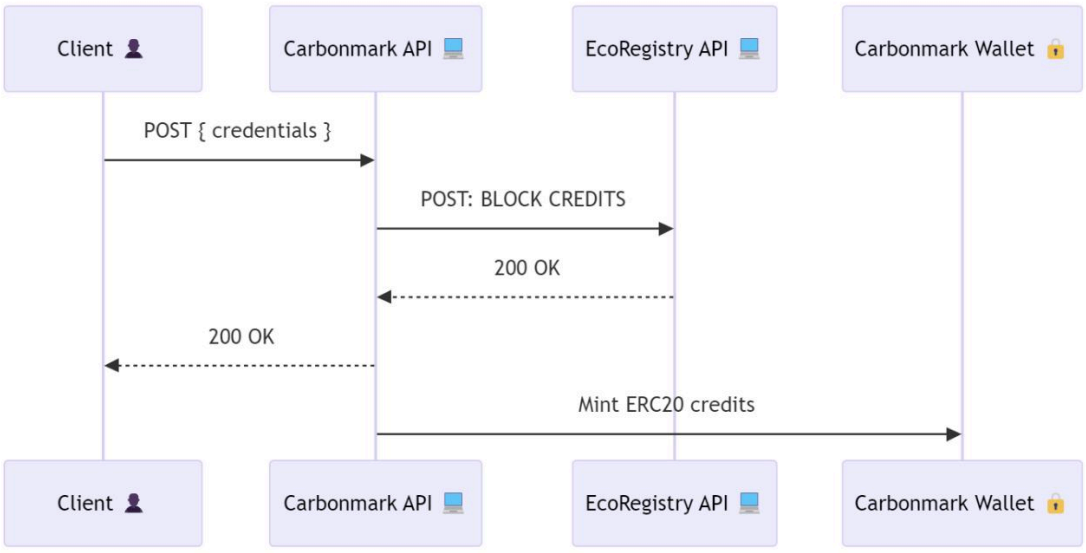


EcoRegistry

EcoRegistry leverages Distributed Ledger Technology (DLT) to enhance the carbon market ecosystem by ensuring traceability, integrity, and efficiency in environmental asset transactions. It enables the tokenization of carbon credits with detailed attributes, creating robust, resilient, and transparent systems supported by cryptographic signatures and smart contracts.

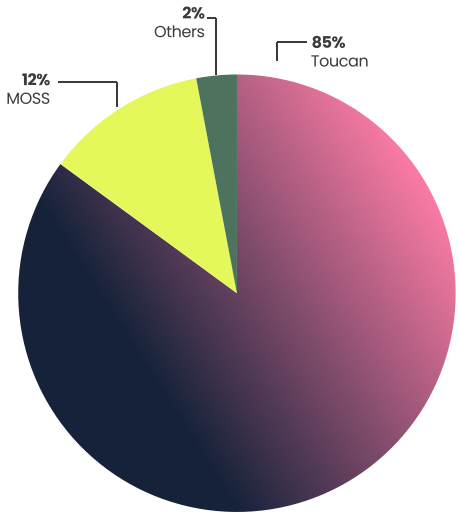
EcoRegistry's Multichain Blockchain Network supports interoperability with platforms like Ethereum, Polygon, and others, enabling seamless integration with marketplaces such as Carbonmark, which provides buyers with comprehensive project data. Since its inception in 2017, EcoRegistry has issued over 100 million tons of CO_2 credits, primarily through the Cercarbono Standard, and has implemented specialized solutions for Monitoring, Reporting, and Verification (MRV) and Nationally Determined Contributions (NDC) tracking.

EcoRegistry's integration with Carbonmark exemplifies how blockchain technology facilitates interoperability between carbon registries and marketplaces, reducing fragmentation and simplifying market participation. Users benefit from seamless access to diverse carbon projects, standardized data sharing, and efficient cross-platform asset transfers.



4.2. Carbon Credit Bridges

Carbon bridges (i.e., credit transfer protocols) such as Carbonmark, Toucan, and Moss play a pivotal role in the tokenization process, converting traditional off-chain carbon credits into on-chain assets. Tokenization enhances the traceability of credits and enables the technical benefits of the blockchain to be realised by the underlying asset.



As of January 2025, the supply of on-chain carbon credits has increased to approximately 27 million, up from 24.5 million in January 2024. Most of these credits remain tokenized through the Toucan carbon bridge, which accounts for about 85% of the total supply.

Toucan

Toucan develops technology to scale climate finance, focusing on the tokenization of off-chain assets, defining carbon reference token criteria that allow heterogeneous carbon credits to be pooled together for enhanced liquidity, and providing carbon data solutions.

Currently, Toucan offers two carbon asset class tokens: Nature Carbon Tonne (NCT) and CHAR, a carbon pool that facilitates the seamless buying and selling of biochar carbon credits. CHAR aggregates verified CO_2 Removal Certificates (CORCs) from Puro.earth.

Toucan's pioneering work in carbon credit tokenization has helped establish deep liquidity for reference tokens like NCT, making carbon credits easily tradable and composable within DeFi.

Toucan's Permissionless Pools

Toucan and Puro.earth have collaborated to launch $CHAR, a tokenized biochar carbon credit designed to improve the liquidity and accessibility of carbon credits. Toucan's infrastructure enables the bridging of CO_2 Removal Certificates (CORCs) issued by Puro.earth onto the Base blockchain, where they are aggregated into a single, fungible asset. This process standardizes biochar credits, making them easier to trade.

$CHAR leverages Automated Market Makers (AMMs) to create permissionless, always-on liquidity, allowing market participants to buy and sell credits based on clear price signals without intermediaries. This system eliminates counterparty risk, ensures real-time price discovery, and reduces transaction costs compared to traditional carbon markets.

Additionally, smart contract mechanisms developed by Toucan allocate a portion of secondary sales to original project developers, ensuring ongoing funding for carbon removal initiatives.

4.3. Decentralized Platforms: Regen

Regen Network is a decentralized platform that creates high-integrity ecocredits to support regeneration and sustainable land stewardship. Integrating governance at both local and protocol levels enables communities to define and manage ecological value through transparent, community-driven mechanisms.

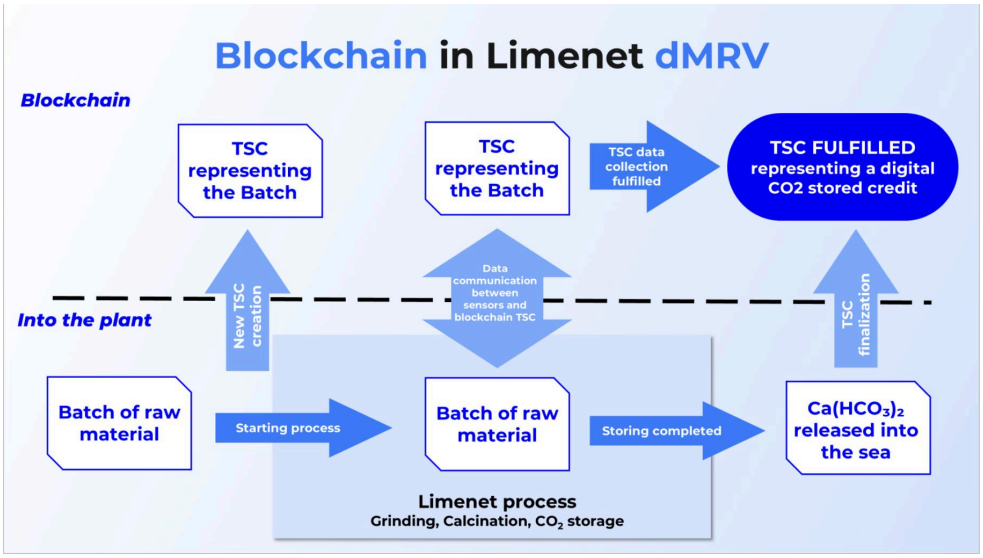
Ecocredits, Regen's primary tool, incentivize regenerative actions by quantifying and compensating environmental and social benefits, such as carbon sequestration and biodiversity preservation.

Using its application-specific blockchain, Regen Ledger, the platform ensures trust and integrity through decentralized verification, transparent record-keeping, and compliance with standards. Additionally, decentralized governance models, known as community-staking DAOs (csDAOs), promote inclusive participation and equitable resource distribution, enabling regenerative projects to scale effectively.

4.4. dMRV + credit issuance

Blockchain technology permits the storage of digital Monitoring, Reporting, and Verification (dMRV) data on-chain for carbon credits by integrating real-time data collection, tokenization, and transparent record-keeping.

Projects like the Soil Carbon Sequestration Project by Alberami and the Ocean Alkalinity Enhancement Project by Limenet use dMRV systems like IoT devices, sensors, satellites, drones, or other monitoring tools to collect accurate, real-time data on carbon offset projects. Then, the data is verified by Validation and Verification Bodies (VVBs) to ensure its accuracy and compliance with regulatory standards.



Blockchain serves as a distributed ledger where **dMRV data is recorded immutably and transparently**. Decentralized oracle networks like Chainlink may be used to connect dMRV systems with blockchain platforms, ensuring seamless transfer of real-world data onto the blockchain.

Verified carbon credits are tokenized into digital assets, with metadata that includes details such as project type, vintage year, and unique identifiers from the original registry, ensuring traceability.

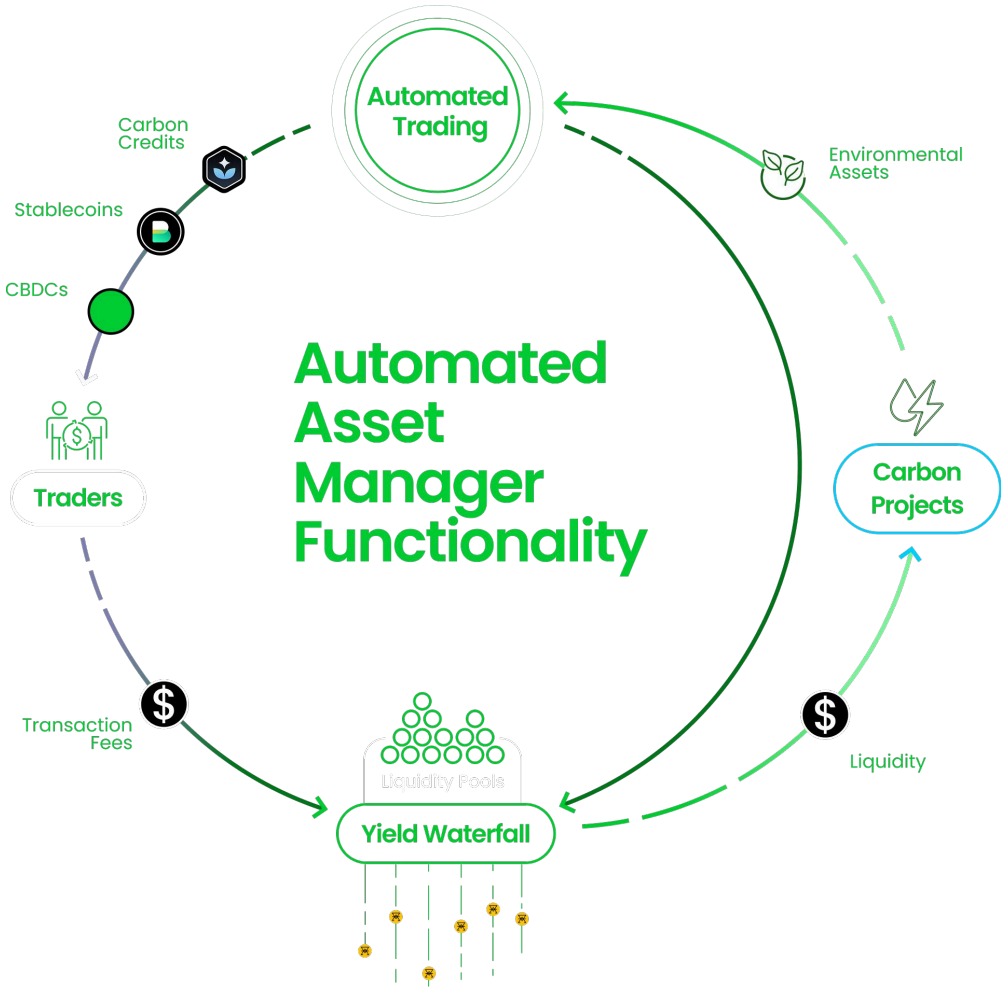
dMRV-enabled tokens representing carbon credits will have the capability to dynamically update their data values based on real-time data pipelines. Ultimately, these advancements are leading to the next generation of carbon credits, where issuance itself can be governed and automated by validated data collection mechanisms, with associated dMRV data stored on publicly verifiable blockchains.

4.5 Market Maker: Klima Protocol

Klima Protocol is the liquidity hub for on-chain carbon credits, managing a portfolio of approximately 20 million carbon credits. Its platform enhances market accessibility and transparency through carbon credit retirement infrastructure, smart contracts for trading, and publicly available data dashboards.

To address VCM oversupply, Klima Protocol has implemented strategic burns using excess treasury profits, helping stabilize carbon prices. Before the Klima 2.0 relaunch, the protocol had already retired 285,000 carbon credits.

KlimaDAO introduces new financing models, enabling community-governed capital allocation to vetted carbon projects. Through tokenized governance and public voting, KlimaDAO directly funds carbon projects, bypassing traditional opaque funding channels and increasing market liquidity.



4.6 Funding and Accelerating Decentralized Solutions: Klima Foundation

Klima Foundation drives innovation in carbon markets by developing open-source technologies and supporting projects that enhance transparency, efficiency, and impact. Through funding, incubation, and sharing technical expertise, we enable the development of decentralized solutions that strengthen carbon market infrastructure.

Klima Foundation actively funds project developers through forward financing, directing over $2.8 million toward high-impact climate initiatives. Its growing market presence enables it to channel reserves into impactful initiatives like Limenet's Ocean Alkalinity Enhancement project in Italy, Improved Cookstoves for Rohingya Refugees in Bangladesh, an Afforestation Project in Uganda, the Hygiene and Environmental Care for Tanks and Overhead Reservoirs (HECTOR) project in India, the Kwamisa Forest Project in Ghana, and many more, supporting scalable carbon removal and emissions reduction solutions.

PROJECT	TONNAGE IN PIPELINE	CAPITAL ALLOCATED	COST PER TONNE	VINTAGE
Improved Cookstoves for Rohingya Refugees **Bangladesh**	**31,250**	**$250,000**	**$8.00**	**2023: 15,625** **2024: 15,000** **2025: 625**
Kwamisa/Other Reserves Community **Ghana**	**14,276**	**$227,000**	**$15.90**	**2023: 10,798** **2024: 3,478**
Ocean Alkalinity Enhancement with Limenet **Italy**	**1,000**	**$600,000**	**$600.00**	**2024: 1,000**
GRO Foundation ARR **Uganda, Kenya**	**15,151**	**$250,000**	**$16.50**	**2024: 309** **2025: 1,011** **2026: 2,371** **2027: 4,611** **2028: 6,850**
IOT Water Filtration **India**	**54,000**	**$810,000**	**$14.75**	2024: **27,000** 2025: **27,000**
Easychar Biochar **UK**	**3,000**	**$249,990**	**$83.33**	2025: **3,000**
ExoMad Green Biochar **Bolivia**	**2,500**	**$350,000**	**$140.00**	2024: **2,500**
J-Credits **Japan**	**1,000**	**$35,000**	**$3.50**	
TOTAL	**121,171**	**$ 2,736,879**		

5. A New Era for Carbon Markets

While the VCM has faced headwinds, it is thriving in 2025, driven by innovation and collaboration among diverse stakeholders. Carbonmark has witnessed firsthand the growing demand for voluntary carbon credits and the potential to unlock new market opportunities.

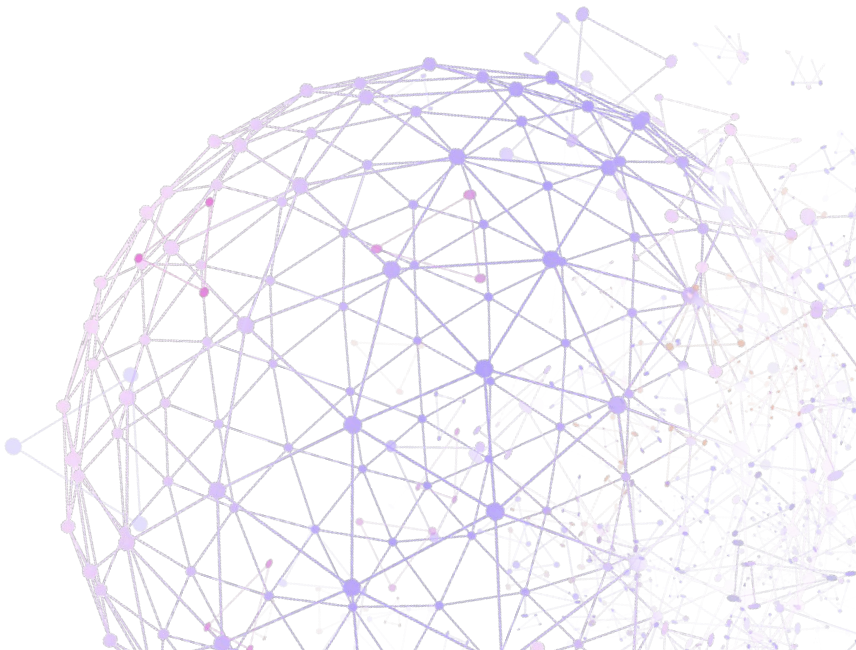
Innovation—from both established market players and new entrants leveraging blockchain technology—has led to an enhanced technology stack, strengthening the VCM's trust infrastructure.

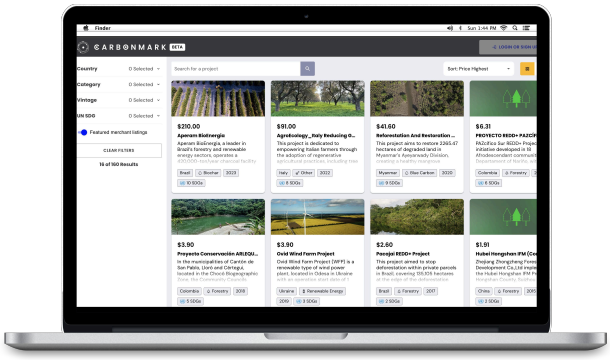
This new era for carbon markets will drive the achievement of the market's growth targets. Our role is to provide the right tools, platform, and interface to enhance the efficiency and interoperability of this increasingly dynamic market.

5.1. Carbonmark's platform offering

Carbonmark aims to create a user-friendly, transparent, and efficient marketplace that democratizes access to carbon credits, facilitating broader participation in climate mitigation efforts. We strive to enhance efficiency by eliminating intermediaries, reducing transaction times, offering transparent pricing, and providing automation tools for seamless trading—all powered by blockchain technology.

Our company offers a growing range of products and services for stakeholders in the carbon market and beyond.





Carbonmark Marketplace

Our flagship product is a robust, integrated peer-to-peer marketplace designed to enhance carbon credit transparency, efficiency, and liquidity. Projects such as the mangrove restoration initiative in Myanmar and the wind power project in Gujarat exemplify the impactful initiatives now accessible through the marketplace, each contributing to a sustainable future while advancing multiple Sustainable Development Goals (SDGs).

Market participants can easily access the marketplace, list carbon credits they hold in inventory, and benefit from buying activity facilitated by digital-native intermediaries that accelerate and automate credit purchases.

Carbonmark API

Carbonmark's aggregation of diverse carbon credit types—including those from pioneering blockchain-native carbon registries and those leveraging innovative dMRV processes—is accessible to software developers via API. This enables demand-side participants to efficiently source high-integrity carbon credits, automate purchases, and facilitate fractionalized retirements when needed.

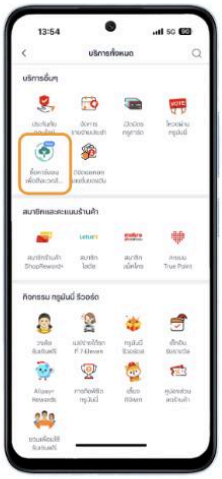
The API can be used to enhance partners' internal carbon sourcing and offsetting efforts, reducing overhead costs for market access. Additionally, partners can integrate the API to expand their existing service offerings by providing carbon credits to their customer base —as demonstrated by Ascent Bit Corp's integration with Carbonmark.

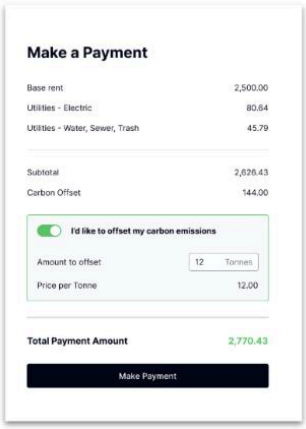
With the new self-serve API offering, developers can quickly get started independently, accelerating integration and reducing setup friction. Learn more in our developer documentation.

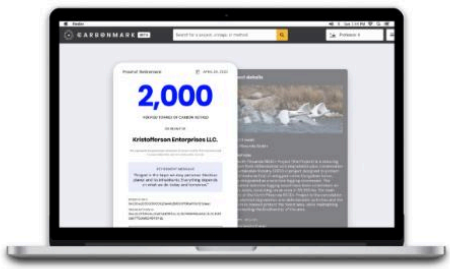
Carbonmark API integration success stories

Ascend Bit Corp, a blockchain solutions company under Thailand's Charoen Pokphand Group, has partnered with Carbonmark to integrate carbon offset features into TrueMoney Wallet, the country's largest fintech app with 20 million monthly active users. Through Carbonmark's API, users can offset 70-930 kg of carbon for 7, 30, or 90 days, with transactions recorded transparently on the blockchain. This innovation simplifies climate action, allowing users to support verified environmental projects like forestry and renewable energy with just a few taps. After a one-month soft launch, over 27,000 users purchased carbon credit, offsetting carbon equivalent to 180,000+ trees. By automating offsets and ensuring real-time verification, Ascend Bit addresses rising consumer demand for sustainability while enhancing user trust and engagement.

Another company - Spherity, a global leader in digital identity management, integrated Carbonmark's API into its Digital Product Passport (DPP) framework to automate carbon offsetting within supply chains. This integration addresses the challenge of complying with the EU's Ecodesign for Sustainable Products Regulation (ESPR), which promotes a circular economy and product lifecycle transparency. By automating carbon offset transactions, Spherity ensures real-time, blockchain-secured openness, enabling clients to meet sustainability and regulatory goals more efficiently. Carbonmark's API facilitates instant transaction settlements, automated offsetting, and comprehensive reporting, reducing manual effort and enhancing operational scalability.







Carbonmark Direct

Carbonmark Direct empowers innovative carbon project developers with a streamlined, transparent, and cost-effective solution for issuing, managing, and selling carbon credits. Leveraging blockchain technology, the platform ensures auditable and traceable credits while supporting emerging methodologies such as DACCS, BECCS, and Enhanced Rock Weathering. With features like rapid credit issuance, integration with advanced dMRV technology, and direct marketplace access, Carbonmark Direct simplifies the journey from project registration to revenue generation, offering developers unparalleled control and transparency.

Pioneering Onchain Limenet Carbon Credits with Carbonmark Direct

Limenet, an Italian startup revolutionizing ocean-based carbon removal, has partnered with Carbonmark to issue its innovative carbon credits on a blockchain-powered platform. This collaboration enables faster, cost-effective issuance of Limenet Carbon Credits, backed by immutable records for transparency and credibility. Limenet's unique pH-equilibrated ocean alkalinity enhancement technology captures CO2 and stores it as calcium bicarbonate, tackling climate change and ocean acidification. Limenet's pilot plant in Augusta (Italy) is the biggest CDR plant in the world based on pH-equilibrated OAE. It has the capability of removing 800 tonnes of CO2 per year. With Carbonmark, Limenet gains access to a global marketplace, API integration, and advanced functionalities like fractional credit sales, broadening accessibility to high-quality carbon removal solutions. The platform ensures seamless credit management, transparent transactions, and scientific rigor, boosting buyer confidence. Their partnership has yielded results, including a forward credit sale to KlimaDAO, positioning Limenet as a trusted innovator in scalable, impactful climate solutions. Limenet and Carbonmark set a new standard for integrating blockchain technology into the voluntary carbon market.

5.2. Carbonmark's vision

Throughout the past years of working with project developers, registries, infrastructure developers, and carbon credit consumers alike, it has become clear that we are entering a new paradigm where more transparent and integrated systems are essential to a high-integrity VCM. Innovation is accelerating rapidly.

Our experience at Carbonmark shows that the VCM, among broader environmental markets, is a crucial component of the solution to climate change. Carbonmark's mission is to provide a platform that serves as a gateway to environmental markets, facilitating the flow of value and information across them for the benefit of our planet, people, and economy.

Carbonmark is committed to addressing the VCM's core challenges by:

- **Prioritizing high-impact projects** that yield meaningful carbon mitigation and removal outcomes, along with strong co-benefits.
- **Expanding our API offering** to enable more automated integration solutions, fostering innovation and increased market throughput.
- **Partnering with leading registries and platforms** to integrate blockchain-backed dMRV tools, enhancing transparency and trust across the entire lifecycle of a carbon credit.

In this way, Carbonmark will not only provide a unified access point to opportunities within environmental markets but also deliver a seamless interface to support their ongoing evolution. This is the essence of Carbonmark's vision: **to optimize environmental market accessibility, scale, and impact**.

Carbonmark has been innovating within the VCM since 2021, implementing new technologies across the market's value chain and furthering the development of blockchain-based solutions. By continuing to leverage the team's expertise across environmental markets and financial technology, the company is well-positioned to advance further its vision of increasing the accessibility, scale, and impact of environmental assets. The work continues in 2025.

If you're interested in accelerating climate action with the help of blockchain technology, contact us at **solutions@carbonmark.com.**

We offer tailored solutions for carbon credit buyers, sellers, and software developers. Visit **carbonmark.com** to learn more!