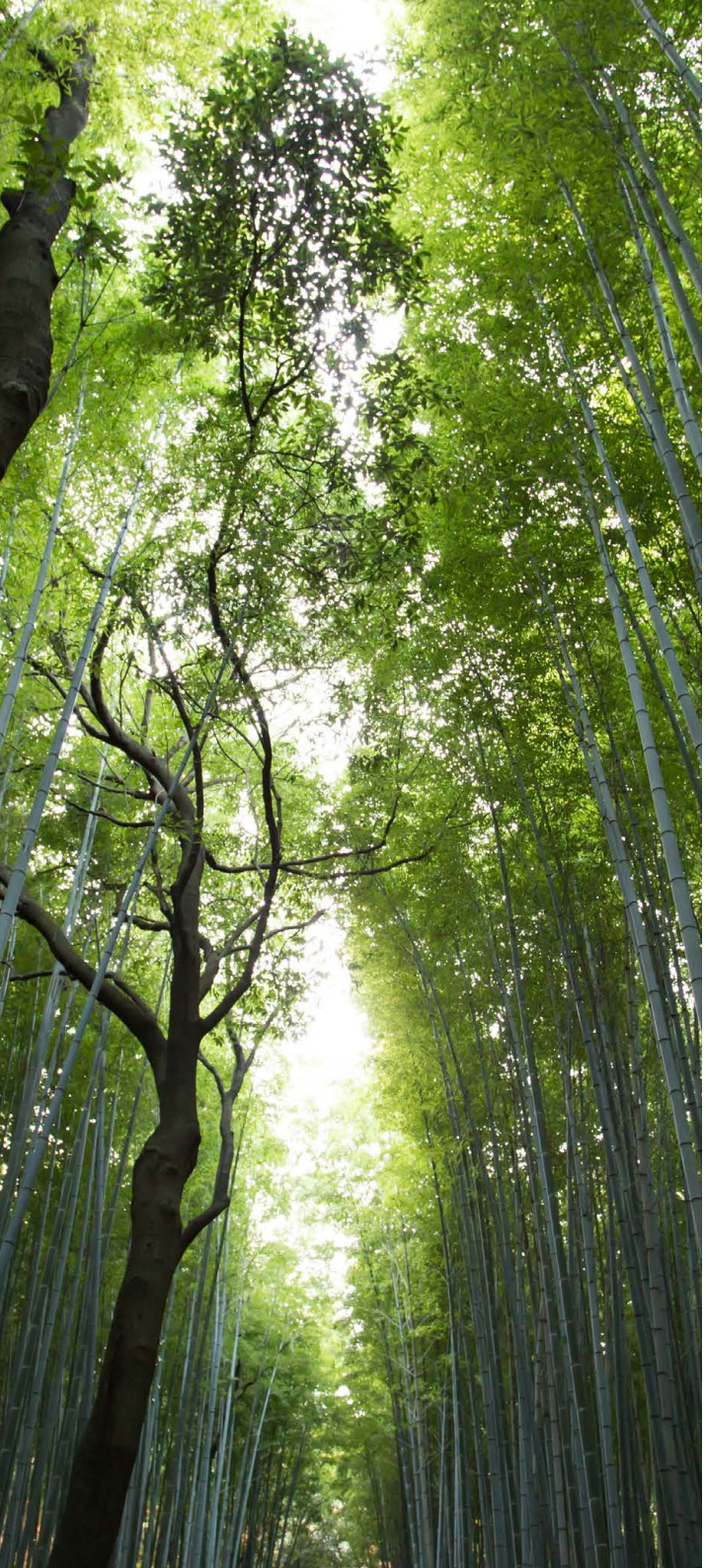
GDF GLOBAL DIGITAL FINANCE

2025 | Report

TOKENIZATION FOR NET ZERO:

THE OPPORTUNITIES AND CHALLENGES OF DIGITALIZING VOLUNTARY CARBON MARKETS



Foreword

Armin Peter
Executive in Residence
Global Digital Finance

Climate change and digital innovation are two of the most defining forces shaping the future of global finance and indeed the future of humankind. As blockchain technology, tokenization, and AI continue to evolve at pace, we are entering a period where sustainability and net zero goals and digital capabilities which have evolved separately are converging in unprecedented ways.

Voluntary carbon markets (VCMs) have existed for decades but have yet to reach their full potential. While tokenized carbon credits already exist, the adoption of digital infrastructure remains limited and fragmented. As the industry grapples with longstanding challenges around trust, transparency, accessibility, and verification, the potential for technology to offer scalable, data-driven solutions is only beginning to be realized. The convergence of traditional carbon markets and digital infrastructure offers new opportunities, not to start from scratch but to scale with intent, applying the lessons learnt in supplementing the traditional financial markets with digital infrastructure.

Tokenization and distributed ledger technologies (DLT) can play a foundational role in addressing these issues - if deployed through collaborative, standards-aligned frameworks.

With the target of halving greenhouse gas emissions by 2030 and demand for high-integrity carbon credits on the rise, it is essential that these markets are built on the strongest possible foundations: trust, interoperability, accountability, and inclusivity.

At Global Digital Finance (GDF), we believe the development of sustainable digital infrastructure is the key to future-proofing financial markets. As a global industry association, we convene leaders across finance, technology, and policy to develop consensus-based standards, promote responsible innovation, and support the digitization of the sustainable finance ecosystem.

This report is part of our ongoing commitment to advancing dialogue and action in this space. To support this ambition, the report concludes with a series of practical recommendations aimed at unlocking the full potential of digital infrastructure for voluntary carbon markets.

The report recommendations span legal, regulatory, and operational considerations, and are intended to help policymakers, market participants, and standard-setting bodies navigate the complexities of scaling these markets responsibly.

By providing a clear path forward, we hope to accelerate collective progress toward a more transparent, inclusive, and high-integrity VCM ecosystem.

Authors and Contacts

Madeleine Boys
Director of Programmes and Innovation
Global Digital Finance

Secretariat
GDF Sustainable Finance
Tokenization Working Group

Deanna Reitman
Partner
Faegre Drinker

Co-Chair
GDF Sustainable Finance
Tokenization Working Group

Emily Julier
Counsel Knowledge Lawyer – Sustainable Finance & Investment
Hogan Lovells

Breige Tinnelly
Head of Market Development
Archax

Co-Chair
GDF Tokenization Forum

Armin Peter
Executive in Residence
Global Digital Finance

Bryony Widdup
Partner
Hogan Lovells

Co-Chair
GDF Sustainable Finance
Tokenization Working Group

Recommendation Overview

The VCM is evolving, but persistent structural challenges continue to constrain its integrity, transparency, and scalability. This report examines these issues in depth - mapping the current standards landscape in Part 2, identifying key market inefficiencies and risks in Part 3, and exploring how DLT and tokenization may address many of these challenges in Part 4. Drawing on practical examples from market participants and pilot initiatives set out in Part 5, the report considers the opportunities and limitations of digital infrastructure in the VCM context.

The recommendations set out below are informed by this analysis. They are designed to support the development of a high-integrity, interoperable, and scalable VCM ecosystem. In doing so, they focus on four core areas: (1) the need for a unified, standards-aligned market framework; (2) the application of tokenization to enhance transparency and price discovery; (3) the embedding of auditability and verification within digital records; and (4) the importance of regulatory support and education to enable responsible innovation.

Together, these recommendations aim to support industry in laying the common foundations for a more trusted, accessible, and efficient carbon market that can scale to meet the demands of the net zero transition. ■

Recommendation 1

Establish a Unified and Standardized Market Framework that Supports Technological Innovation within VCM

Recommendation: Establish an industry-led working group with the support of regulators to develop a common accreditation and reporting framework for tokenized carbon credits, drawing on international best practices and work developed by global standard-setters like IOSCO.

Recommendation 2

Utilizing DLT to Improve Market Transparency and Price Discovery

Recommendation: Enable carbon credit tokenization and recognize its validity in VCM to help to provide real-time price transparency, standardized data on credit quality, and transaction histories to the market.

Recommendation 3

Enhance Trust and Integrity Through Independent Verification and Auditable Digital Records

Recommendation: Leverage DLT-based technologies and tokenization to embed verification data, independent audit trails, and third-party validation mechanisms directly into carbon credit transactions, enhancing certainty of provenance and full traceability from issuance to retirement.

Recommendation 4

Regulatory and Policy Support for Education and Innovation in Tokenized Carbon Markets

Recommendation: Consider introducing an industry-led sandbox for tokenized carbon markets (or introducing a focus theme into an existing sandbox structure), allowing market participants to test carbon credit tokenization models within a controlled environment. This could support process and procedure improvements, standards and market participant expectations alignment, and the identification and mitigation of risks, while fostering innovation. Capacity building across public and private sector as to how the potential efficiencies and improvements realized through technological innovation will be important too.

PART 1

INTRODUCTION AND BACKGROUND

Development of carbon markets

In recent years, climate change has emerged as a defining challenge of our time, compelling both public and private sectors to rethink their environmental strategies. Global consensus on the urgent need for climate action has been shaped by pivotal international agreements such as the Paris Agreement, which has catalyzed a shift towards sustainability across industries. This global framework, adopted at COP21 in 2015, has been instrumental in aligning nations and businesses around the goal of limiting global temperature rise to well below 2°C, with efforts to restrict it to 1.5°C.[1]

Against this backdrop, the private sector, driven by regulatory expectations and market pressures, has accelerated investments in climate technology. Over the past decade, such investments have outpaced global startup growth by a factor of five, reflecting a clear recognition of the need to address climate risks and contribute to decarbonization goals. These trends are not only a response to regulatory frameworks but are also driven by the financial sector's growing commitment to addressing environmental, social, and governance (ESG) related risk.[2]

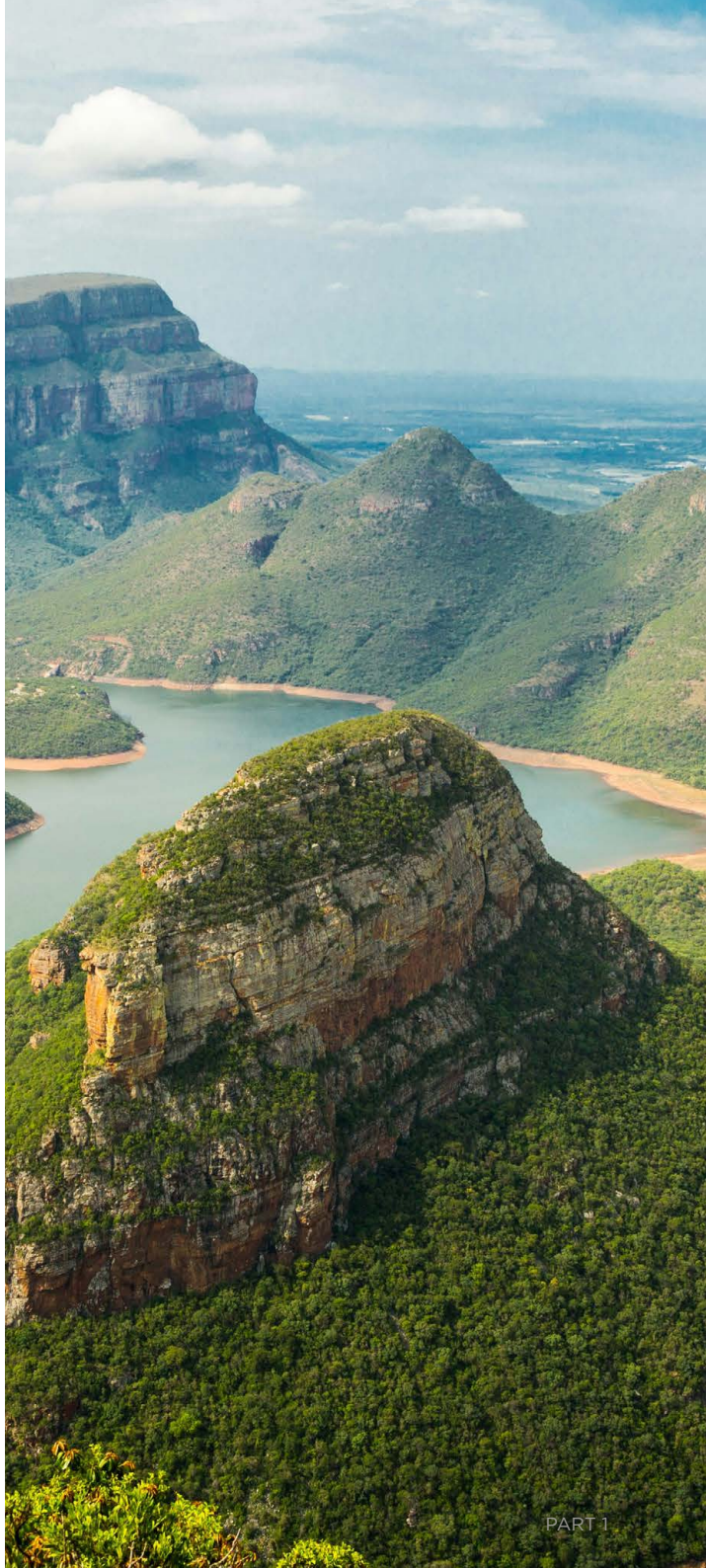
Carbon and nature credits, (including biodiversity, water and other types of credits which are emerging), have become an essential mechanism for organizations to meet their sustainability targets. They serve as a versatile tool, generating funding and incentives for projects that promote positive environmental outcomes.

To address these environmental priorities in particular, an increasing number of companies are committing (including being required through various mechanisms to commit, or otherwise undertaking voluntary activities) to reducing their greenhouse gas (GHG) emissions. However, fully eliminating emissions or achieving rapid reductions presents significant challenges, particularly for companies striving to reach net zero goals, which require balancing emitted and removed GHG.

Carbon trading and carbon markets offer a critical tool for organizations in this respect. By focusing specifically on reducing or removing GHG emissions, carbon credits allow organizations to offset their carbon footprints while supporting broader ecological and sustainability goals. Time is short. With only five years left to meet 2030 commitments, the growing importance of focused mechanisms like the VCMs are clear in addressing the urgent need for climate action.

Understanding the different types of credits and markets

There are different types of credits and markets, including mandatory and voluntary. The **compliance market** is governed by mandatory national, regional, or international GHG emissions reduction frameworks, typically affecting large corporations and government entities. Participants are required to cap their GHG emissions according to specific quotas and are granted allowances up to such quotas. The participants then can emit up to the allowances, emit less than the allowances, which allows the participant to either retire or sell such extra allowances, or purchase additional allowances, which allows the participants to emit above their specific quota.



[1] https://unfccc.int/process-and-meetings/the-paris-agreement
[2] https://www.statestreet.com/ca/en/asset-owner/insights/carbon-assets-tokenization

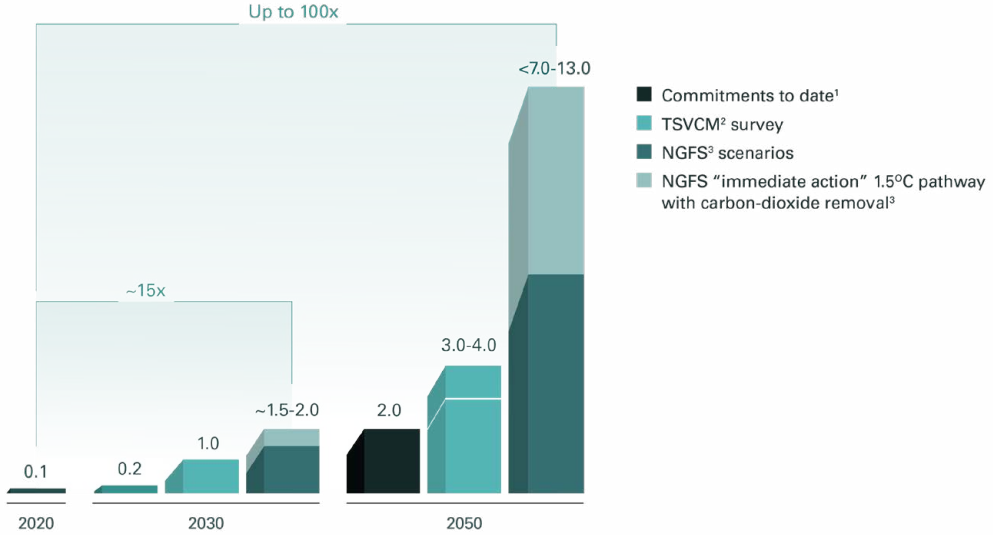
There is also a **VCM** which has historically operated independently of compliance markets, allowing businesses and individuals to generate, sell and buy carbon credits voluntarily. These purchases are often motivated by goals related to corporate social responsibility, anticipation of future regulations, requirements imposed by financing agreements or as a result of customer or other stakeholder obligations, or speculation on future commodity values. VCMs provide a flexible, market-driven mechanism to finance projects that reduce or remove GHG, while also supporting broader environmental goals such as biodiversity conservation and ecosystem restoration.

However, the current VCM landscape is fragmented and complex. Inconsistencies in the type and quality of carbon credits, questions about the legitimacy of some projects, challenges with double-counting, differentiated verification standards and limited price transparency make it difficult for participants to navigate the market with confidence.

Drawing from the principles of Gresham's Law, where inferior quality goods drive superior quality ones out of circulation, the carbon credit market faces a similar risk. If higher and lower quality carbon credits are available, there is a risk that those who have access to these higher quality credits remove them from circulation thus leaving the broader market with lower quality credits. An overall lower quality carbon credit market would undermine confidence among market participants seeking genuine decarbonization outcomes. This imbalance could lead to speculative bubbles, with market participants chasing short-term gains over long-term sustainability goals and could also disincentivize participation altogether, reducing the number of buyers and sellers and ultimately leading to the demise of VCMs.

Global demand for voluntary carbon credits could increase by a factor of 15 by 2030 and a factor of 100 by 2050.

Voluntary demand scenarios for carbon credits, gigatons per year



Source: McKinsey - A blueprint for scaling voluntary carbon markets to meet the climate challenge

Addressing these challenges is vital if VCMs are to scale effectively to support participants in reaching their goals and to meet rising demand for carbon credits. VCMs need to learn from other financial markets which teach that the most successful areas are effectively integrated with other capital markets activities to build high quality, liquid and mature asset classes. Trust, consistency and integrity of approach and diverse participation are essential to ensure a deep and liquid carbon credit market.

This report provides analysis of today's VCM landscape, its current challenges, and the transformative role that distributed ledger technology (DLT) and tokenization can play in addressing existing issues. Tokenizing carbon credits offers clear, verifiable data in relation to the carbon units represented by credits and to encourage greater depth of market participation, involving individuals and corporations with sustainability goals and financial institutions focused on long-term value creation. Transparency helps to democratize access, improving the demand side and helping to ensuring that higher-quality credits remain in circulation rather than being accessed bilaterally, or only by select participants.

VCM market size and growth

As of 2023, the voluntary carbon credit market is valued at approximately $2–4 billion.[3]

This market is expected to experience an average compound annual growth rate of approximately 31% between 2023 and 2028, underscoring the substantial growth potential in these segments and global consulting firm McKinsey forecasts that it could grow

[3] https://medium.com/rwa-world/tokenization-taxonomy-esg-part-3-carbon-credits-94485d211d7d

between 2023 and 2028, underscoring the substantial growth potential in these segments. Global consulting firm McKinsey forecasts that it could grow by a factor of 15 by 2030 and by 100 by 2050, with the market size projected to reach around $50 billion by 2030.

The VCM is becoming a major source of funding for not only GHG emissions reduction and removal projects, but also for environmental protection projects, providing finance for such activities through the forward sale of the carbon credits on the VCM.

The role of carbon credits in driving targeted climate action

A carbon credit is a nonfinancial environmental commodity that can be physically delivered and transferred, representing one tonne of carbon dioxide equivalent reduced, or removed from the atmosphere. Project developers and companies holding carbon credits sell such carbon credits to other companies who retire, or consume, the carbon credit to claim a reduction in their GHG or claim contribution to climate change mitigation.

To create a viable and consumable carbon credit, the mechanism's used to generate a GHG reduction or removal must be conducted in a fashion that satisfies the requirements of an applicable VCM standard and methodology. There are multiple mechanisms, but most often carbon credits are created through:

a. Project development and/or the operation of a project that additionally reduces or removes greenhouse gases, or

b. Corporate initiatives or practices that are purposely modified in order to reduce or remove greenhouse gases.

The VCM is becoming a major source of funding for not only GHG reduction and removal projects, but also for ecosystem protection projects, providing finance for such activities through the forward sale of voluntary carbon credits. ■

.

PART 2

EXISTING STANDARDS, REPORTING PROTOCOLS, AND REGULATIONS

The integrity of the VCM is paramount to its success in driving meaningful climate action. Carbon credit standards play a critical role in maintaining this integrity by setting criteria for transparency, accountability, and reliability in carbon credit issuance.

There are a large number of existing standards agencies which provide registry services, which each have different sets of standards for their credits (driving market complexity, potentially shadowing quality issues, creating interoperability challenges and preventing carbon credit fungibility).

This section set outs several prominent carbon credit standards, some of whose trading volumes and relative market shares are outlined in the table below. The purpose of this section is to emphasize the criteria of integrity that are upheld across these frameworks and highlight the commonalities integrity criteria across them.

The **Verra Carbon Standard (VCS)** is one of the most widely recognized standards for voluntary carbon markets. It upholds rigorous requirements for additionality, verification, and permanence. Key integrity principles include:

- **Additionality:** Projects must demonstrate that they would not have been financially or operationally viable without the incentive of carbon credit revenues.
- **Third-party verification:** All projects undergo independent validation and verification to ensure that emissions reductions are real and quantifiable.
- **Permanence:** Verra mandates that projects incorporate mechanisms to mitigate the risk of emissions reversals. For example, forest conservation projects must establish buffer reserves to compensate for any carbon loss.
- **Transparency:** Verra maintains public registries where all project documentation, verification reports, and credit issuances are recorded, ensuring full transparency.

The **Gold Standard** is a widely respected carbon credit standard that integrates sustainable development objectives into carbon market mechanisms. In addition to additionality, permanence, and third-party verification which are common to many of the aforementioned standards, the Gold Standard framework is built on high environmental and social integrity with core features that include:

- **Sustainable development co-benefits:** In addition to reducing or removing GHGs, projects must contribute positively to at least three UN Sustainable Development Goals (SDGs), verified through performance indicators.
- **Stakeholder inclusivity:** Projects are required to conduct comprehensive stakeholder consultations, ensuring that local communities are engaged, risks are identified, and benefits are equitably distributed.

The **American Carbon Registry (ACR)** focuses on ensuring that carbon credits represent genuine emissions reductions through strict adherence to additionality, permanence, and accurate measurement. Key integrity criteria include:

- **Additionality**: ACR requires projects to pass a "three-pronged test" to ensure emissions reductions are beyond what would have occurred under existing laws or typical industry practices.
- **Permanence:** Projects must monitor and mitigate risks of emissions reversals. ACR implements reversal compensation mechanisms to ensure that reductions remain permanent.
- **Validation and verification:** Independent third-party verification is required for both project design and emissions outcomes to maintain accountability.
- **Avoiding double counting:** ACR uses transparent registries and strict oversight to prevent double issuance or double use of carbon credits.

Table 7. VCM Transaction Volumes, Values, and Prices, by Project Standard, 2022 - 2023

	2022			2023			Percent Change		
Standard	Volume ($MtCO_2e$)	Value (USD)	Price (USD)	Volume ($MtCO_2e$)	Value (USD)	Price (USD)	Volume	Value	Price
VCS	158.0	$1.3 B	$8.07	56.2	$382.3 M	$6.81	-64%	-70%	-16%
Gold Standard	20.9	$159.0 M	$7.60	15.8	$99.8 M	$6.31	-24%	-37%	-17%
ACR	3.5	$59.5 M	$17.01	10.7	$60.7 M	$5.66	+206%	+2%	-67%
CDM	37.7	$73.0 M	$1.94	6.9	$18.0 M	$2.63	-82%	-75%	+36%
CAR	3.1	$14.2 M	$4.56	3.2	$24.0 M	$7.43	+4%	+70%	+63%
Plan Vivo	2.1	$27.5 M	$13.06	1.6	$18.7 M	$11.52	-23%	-32%	-12%
Cercarbono	4.1	$23.5 M	$5.73	0.48	$1.9 M	$4.04	-88%	-92%	-29%
UK Woodland Carbon Code	0.21	$5.2 M	$24.41	0.16	$4.7 M	$29.17	-24%	-9%	+20%

Source: Ecosystem Marketplace - State of the Voluntary Carbon Market 2024

The **International Carbon Registry (ICR)** emphasizes transparency, rigorous quantification, and safeguards to maintain integrity. Core integrity criteria include:

- **Robust quantification:** ICR employs scientific methodologies to ensure GHG reductions are accurately measured and conservative in approach, preventing overestimation.
- **Additionality:** Projects must demonstrate a net environmental benefit that would not have occurred without the project.
- **Permanence:** A minimum 50-year term of permanence is required for GHG reductions, ensuring that emissions are not reintroduced into the atmosphere.
- **Leakage prevention:** ICR accounts for and deducts potential leakage (the shifting of emissions) to ensure the real impact of a project.

The **Science Based Targets Initiative (SBTi)** sets standards for companies aiming to reduce their emissions in line with climate science. Though SBTi does not directly create carbon credits, it provides guidance on how companies should use carbon credits as part of their broader emissions reductions strategies:

- **Within-value-chain emissions reductions:** SBTi emphasizes that companies should prioritize reductions within their own value chains before using carbon credits for offsetting.
- **High integrity:** Credits used to offset residual emissions must meet high integrity standards and should only be applied toward unavoidable emissions.
- **Transparency and accountability:** SBTi requires companies to publicly disclose their use of carbon credits and demonstrate that they align with long-term net zero goals.

The **EcoRegistry** platform ensures traceability and transparency of carbon credit projects. The system allows for the secure registration of environmental assets with the following integrity features:

- **Modularity and traceability:** EcoRegistry incorporates stages defined by protocol, ensuring that all project documentation and data are transparent and accessible.
- **Compliance:** The platform monitors compliance at every stage, enabling real-time tracking and accountability for all projects.

The VCM stands at a critical juncture – market integrity demands robust and consistent data-driven accounting which is essential to address multiple issues that have undermined confidence to date. The standards that have been established at an international level, derived from Article 6 of the Paris Agreement and devolved into science-based target, sustainability accounting and registry verification practices, do and will continue to play a vital role in ensuring carbon credits represent real, measurable, and verifiable emissions reductions, with key criteria such as additionality and permanence consistently prioritized across all frameworks.

Nonetheless, continuous standards enhancement is required, particularly the delivery of more direct data-driven accountability through carbon credits (driving positive real-world impact, minimizing negative externalities, enabling comparability and enhancing consumer understanding), and on transparency. New technologies such as distributed ledger technology (DLT) can help with standards implementation and enhancement, particularly in the areas of transparency, data access and traceability (tracking units from source to credit), offering some solutions for current challenges with data quality (including delayed data provision), reporting inconsistencies and transparency gaps, that reflect known shortcomings in existing VCM offerings.

Trust in the status and authenticity of carbon credits is paramount to VCM and without it, trading volume and markets will not grow. DLT can offer a robust infrastructure to complement and strengthen existing carbon standards by enabling a shift from qualitative, trust-based verification to quantitative, data-driven accountability. Supporting carbon credits with digital methods would not only help improve integrity and transparency but also support greater liquidity in markets, improving comparability and easier substantiation of the value of carbon credits (with verifiable, more real-time, data), increasing confidence for market participants. ■

PART 3

CHALLENGES IN VOLUNTARY CARBON MARKETS TO DATE

The VCM is a crucial tool for achieving a positive impact on climate change. It provides a market-based mechanism to incentivize and finance GHG emission reductions, promote sustainable practices, and combat climate change on a global scale. However, participants lack confidence in the market due to instances of inaccurate carbon accounting, fraudulent project claims, and transparency challenges, amongst other things, which may inhibit participation and investment from a broader range of market participants.

Many market participants have attempted to shed light on these challenges – including regulators, policymakers and independent governance bodies who are prioritizing the development of industry-wide standards to help solve them, including:

- The International Organization of Securities Commission (IOSCO) recently issued "Findings from IOSCO Consultation Report to promote the integrity and orderly functioning of the Voluntary Carbon Markets" and a similar report on challenges in Compliance Markets.[7] Amongst the challenges they identify, IOSCO highlights in particular concern around lack of transparency, conduct, and the markets trading environments. Notwithstanding IOSCO's endeavours to address these challenges, it is noted that the Report does not mention tokenization or discuss the use of digital tech and is firmly rooted in the existing technology of the financial markets.

- The Integrity Council for the Voluntary Carbon Market (ICVCM) has set rigorous standards and guidelines that ensure VCM can reliably contribute to global climate goals, including those set in the Paris Agreement. Most notably, the ICVCM Core Carbon Principles (CCP) are ten science-based principles for identifying high-quality carbon credits that create real, verifiable climate impact across three areas including governance, emissions impact, and sustainable development.[8]

- At COP29 in Baku, agreements were reached to further the mechanisms under Article 6 of the Paris Agreement, including on the authorization and transparency requirements and a mechanism for States to trade emission reductions (ERs). But interlinkages between the Article 6 markets and the voluntary carbon markets continue to grow as ERs created by States may be sold to VCM and non-State actors may generate ERs for a State's nationally determined contributions under the Paris Agreement.

Two sets of Standards were adopted in respect of the international carbon crediting mechanism established under Article 6.4 of the Paris Agreement to establish a global crediting mechanism for ERs. The Standards cover (i) methodology principles setting out the basis for claim and assessment of emission reductions or removals (including additionality) and (ii) specific guidelines for emission removal projects (including addressing reversals, avoiding leakage and ensuring that removal does not cause negative impacts to environment and society or human and indigenous rights. Some states, such as the European Union, have introduced their own voluntary certification frameworks for carbon removals.[9]

For the purposes of this report, we delve into different aspects of these challenges and others of concern from market participants and categorized them across five challenge areas. This is with a view to analyzing in a subsequent chapter how distributed ledger technology and some of its applications like real-world asset (RWA) tokenization may address and help solve for some of these challenges.

[7] https://www.iosco.org/library/pubdocs/pdf/IOSCOPD719.pdf

[8] https://icvcm.org/core-carbon-principles/

[9] https://data.consilium.europa.eu/doc/document/PE-92-2024-INIT/en/pdf

Challenge Area #1 – Ensuring positive environmental impact

The challenge of ensuring a positive impact on the environment may be described as difficulties in connecting the tonne associated with each carbon credit to real additional reductions in GHG emission reductions[10]. This challenge may materialize in a number of ways, such as:

- **Integrity questions** – VCM markets have suffered integrity challenges including fraud and issues with project validations which have had affected the reputation of the market and confidence in the critical work and projects they allow for. An example of this kind of issue is of credits not being sufficiently verified and ultimately linked to bogus projects – "more than 90% of [Verra's] rainforest offset credits… are likely to be "phantom credits" and do not represent genuine carbon reductions"[11];

- **Additionality questions** – This speaks to determining whether a project is truly incentivized for avoidance, reduction or removal of GHG emissions that would not otherwise have occurred;

- **Permanence questions** - This refers to calculating how long an avoided, reduced or removed GHG emission will stay out of the atmosphere;

- **Multi-factor questions** - Projects that may be demonstrably effective from a GHG emissions reduction or removal perspective may have human rights issues or negative community impacts associated with them. This close relationship is emphasized in the way in which policies to combat climate change – whether they be driven at a macro supranational, national or micro corporate level – often relate to environmental, social, and governance priorities together. The significance of this is demonstrating that these factors often work in tandem and should extend to VCM markets as well;

- **Vintages, standards and scientific advancement questions** – Buyers often orientate to newer vintages resulting in a lack of support for older vintages. This in turn may mean that project sponsors cannot keep projects afloat thus risking failing on the permanence question described above;

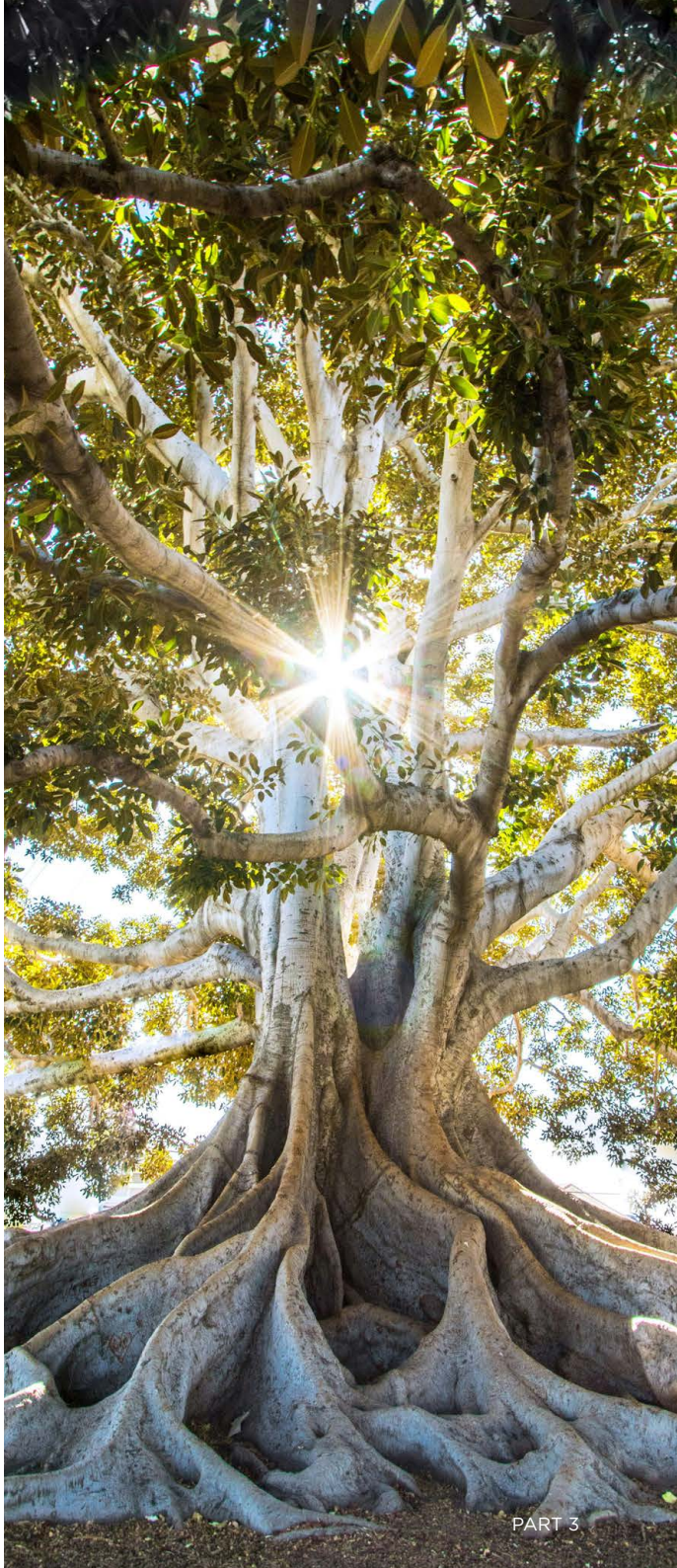
- **Multiple standards and varying certifications of validation and verification bodies questions** – The variance described here speaks to the heterogeneity of standards and validation certificates in VCM markets which can make it hard to compare and measure the relative impact on the environment per carbon credit[12]. The lack of comparability of standards also drives higher due diligence burdens (including in costs and extended timeframes); and

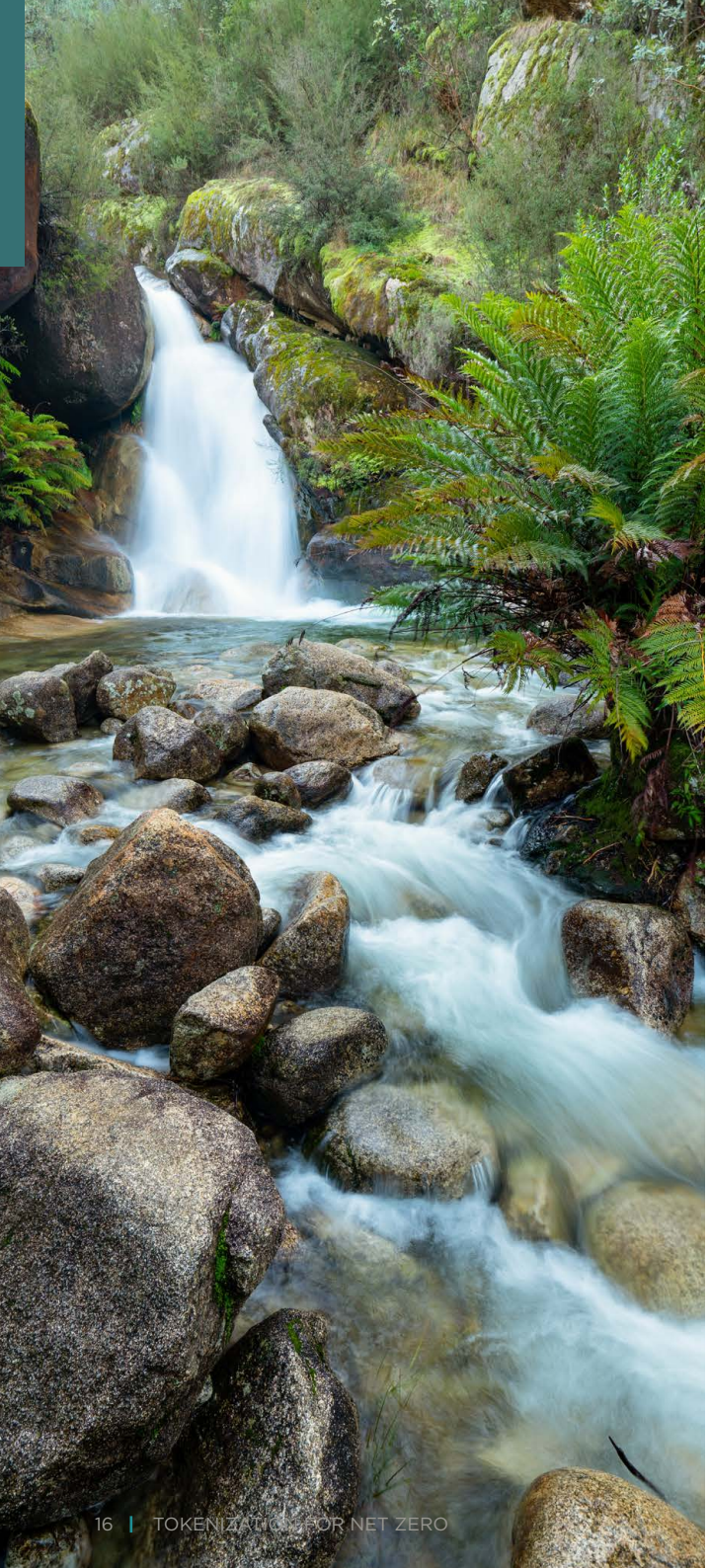
- **Accounting Protocols** – There may also be differences between how projects implement project accounting protocols.

[10] A "tonne" is an established spelling alternative to a metric ton and is equal to 1,000 kg. In the US it may be referred to as a "metric ton".

[11] https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe

[12] https://ieta.b-cdn.net/wp-content/uploads/2023/12/COP28-ICP-joint-statement.pdf





Challenge Area #2 – Transparency

The challenge of ensuring transparency describes ensuring the quality and features of the GHG emission reductions are actively reflected by the carbon credit. Transparency is a multifaceted challenge area in VCM with a number of distinct and complex issues which we attempt to identity below.

First, there is the issue of **transparency around the quality of credits** available to buyers to purchase. All carbon credits are not created equal. There is a need for "high quality credits" to support trust and scaling in the market. However, as described above, there are a myriad of risks associated with ensuring that carbon credits have a positive environmental impact. The issues VCM have seen to date suggest that there are "medium" or "low" quality credits available. The difference in carbon credit quality may not be readily identifiable to buyers due to transparency issues and create risk (e.g. of greenwashing accusations, public relations issues and disputes) for participants.

There is also the concern that **price transparency** may also be lacking. For example, the purchase of carbon credits is usually negotiated bilaterally between counterparties and a number of different factors, including the standard and methodology used, the overall size of the trade, the country in which the GHG emissions reduction or removal occurs. The anticipated permanence of the associated carbon credit and whether multi-factor certification or co-benefits are bundled with the carbon credit, e.g. from a human rights perspective, is also part of the carbon credit value and may all feed into the value of the carbon credit, making price transparency complex for all participants along the value chain.

There may also be a lack of information about the intended **carbon credit's location** and the subsequent **transparency of financial flows**. For instance, a recent Carbon Market Watch report sheds light on the geographic disparity of project actors and project bases, whereby wealthier countries may implement and manage carbon projects actually based in less affluent countries. This can raise doubt as to the transparency of funds and fund management in these projects. Particularly when there is little evidence to suggest that the appropriate share revenue is finding its way to the project.[13]

[13] https://carbonmarketwatch.org/publications/due-south-geographic-disparity-of-project-actors-in-the-voluntary-carbon-market/

Challenge Area #3 – Misalignment between independent accrediting bodies and standards agencies

Despite suggestion of increased attempts at co-operation, there is ongoing fragmentation in the processes and standards applied to verification of carbon credits by the main accrediting bodies. They do not seek common ground amongst themselves and are incentivized from a competitiveness perspective to maintain and amplify nuances, arguing that their standards have supremacy over others. This means that units are not exactly comparable, which could reduce secondary market tradability and the ability to create standardized financial products with the voluntary carbon credit as the underlying commodity. These conditions may not be conducive to a scaled liquid secondary market.

For some existing participants in the market, there may be competitive advantages in maintaining this fragmented status quo, however, this state of affairs is not rationally compatible with the concept that carbon credits are in their core a representation of fungible units – metric tonnes of carbon dioxide equivalents. Finding a commonly acceptable way to represent verification and accreditation of the real-world unitized impact that sits at the heart of the market is key.

This transformation will require a data first approach, where carbon credits are essentially a truly standardized, data driven, commodity. As we start to think of solutions, we can think about any commodity market where everyone has a different standard for what constitutes the different grades – two units of the commodity may be called the same thing but may actually be different as to quality and features.

Challenge Area #4 – Disagreement on digitization in the market

A small number of non-profit accreditation entities that provide registry functions for carbon credits currently dominate the market (See Table 7 in Part 3). The dominant participants have generally "banned" the creation of digital assets tokens that represent or refer to verified credits held in their registries. This is reportedly due to integrity issues that these entities perceive with the creation and trading of carbon tokens, including gaps around "double-spending" problem and lack of definitive retirement.

Clearly any ongoing integrity issues need to be successfully tackled, however, the independent accrediting bodies would need to work with the digital assets providers to achieve that (including on solutions, for example, that offer a hybrid structure whereby credits in traditional registries are frozen and/or retired on creation of linked carbon tokens). Unfortunately, open dialogues remain challenging and accrediting bodies continue to be resistant, citing risks and refusing to acknowledge claims associated with tokenized verified carbon credits. By way of example, one of the largest independent accreditation bodies by market share, VERRA, has an ongoing ban on tokenization.[14]

This situation is creating barriers to entry to the carbon credits market for digital solutions providers and is therefore inhibiting the introduction of some of the benefits that digital solutions can bring (which we will explore in part 4 and 5). However, in general, where we see barriers to entry in markets, we might also expect to see inflated pricing due to insufficient competition in offerings, supply-side controls (which also may be implemented to inflate pricing), standards degradation and a relatively static market size. It is therefore important to explore existing drivers and inherent conflicts of interest for the independent accreditation bodies and see what can be done to open up the market without proliferating additional nuanced standards and fragmentation, which would make it even more complex and confusing for participants and therefore exacerbate existing issues.

[14] https://verra.org/verra-concludes-consultation-on-third-party-crypto-instruments-and-tokens/

Challenge Area #5 – Accessibility and barriers to entry

One of the biggest challenges in the carbon credit market is the significant cost and complexity associated with project registration, validation, and verification.

There are costly expenses involved in listing a project on a recognized registry, undergoing validation, and obtaining verification of GHG reduction or removal. Beyond direct costs, the time required to navigate these administrative processes adds another layer of difficulty. Each step requires significant administrative effort and expertise, often necessitating external consultants or legal assistance. Together, the barriers to entry for community-led or decentralized initiatives, limiting market participation to well-funded organizations.

Beyond this, the negotiation of carbon credit purchases and sales is further complicated by the reliance on bespoke contractual arrangements. This requires specialized legal and financial knowledge to ensure compliance with market standards. And makes transactions inefficient and can deter new market entrants.

Further, fragmentation between independent accrediting and standard-setting/verification bodies makes the market even more complex and confusing for participants, not only preventing an open market with new entrants, but also exacerbating existing trust challenges. These integrity issues are aggravated by the fact that the traditional market's reliance on bespoke (and confidential) contractual agreements makes it inherently difficult to monitor and police.

These trust challenges can be remedied by the automated process that a blockchain-enabled system presents, enhancing trust by providing a transparent and immutable record of transactions, which this report details further in Part 4. ■

PART 4

BLOCKCHAIN AS A SOLUTION

A. Seizing the opportunity: tokenizing the cabon markets

Tokenization refers to the process of converting assets into digital tokens that represent ownership rights on DLT. In so doing, all transactions recorded on a DLT can be traced, audited, and verified in real time, reducing the risk of fraud and increasing market efficiency.

Tokenization has gained significant traction in the financial services industry, particularly for its application to real-world assets (RWA) like real estate, commodities, and financial instruments, enabling liquidity in traditionally illiquid or complex asset markets, fractional ownership, enhanced transparency, and simplified transactions.

Many applications to date have been seen in the tokenization of traditional financial instruments, but increasingly market participants are exploring the potential of tokenization for non-financial commodities like gold and carbon credits.

Tokenization of Carbon Credits

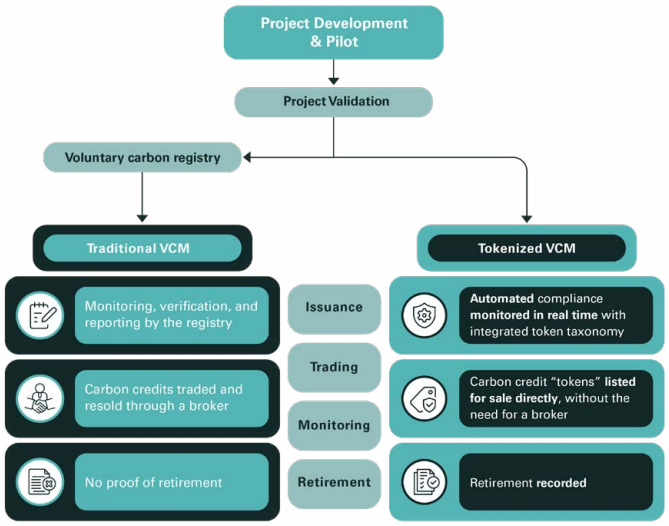
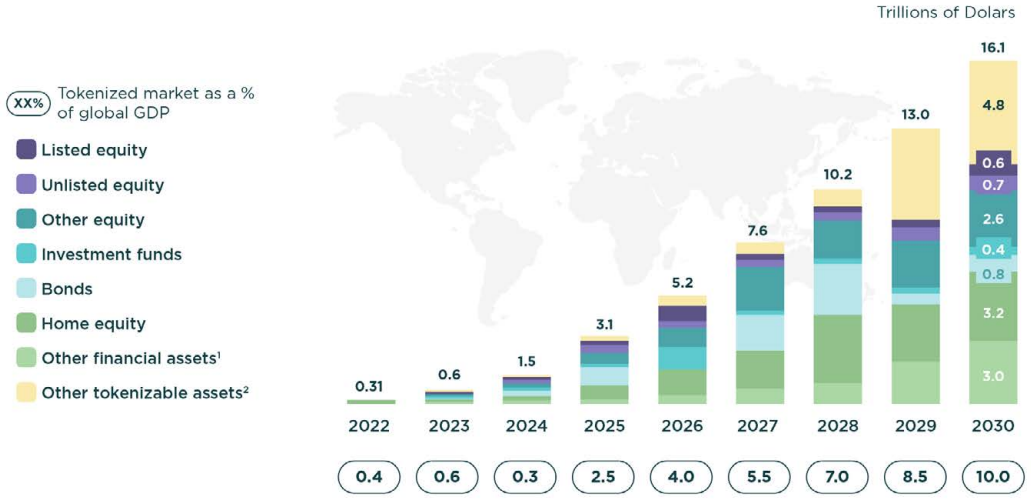


Figure 1 - Carbon Credit Lifecycle in Traditional and Tokenized VCM

Tokenization of global liquid assets estimated to be a $16 trillion business opportunity by 2030

Highly conservative forecast; tokenization potential of $68 trillion by 2030 in best case scenario

Tokenized asset **potential differs across countries** due to variation in maturity of regulations and size of assets classes



Source: GDF and ISSA Digital Asset Custody Deciphered Primer

Total **tokenized market to be 10% of global GDP** by 2030

The tokenization of carbon credits

Applied to carbon credits, tokenization has the potential to transform the VCM and offer a more scalable, secure, and transparent framework for trading carbon offsets. Tokenization addresses many of the challenges discussed in this report by giving each carbon credit a unique digital representation that can be traced from issuance to retirement.[15]

The tokenization of carbon credits follows the same principles seen in traditional finance, allowing for fractional ownership, streamlined transactions, maintenance of the unique attributes for each commoditized tonne of carbon dioxide equivalent, and enhanced transactional and lifecycle transparency through DLT to show transfer of title and encumbrances.

In the sections that follow, we will explore more specifically how tokenization can enhance the integrity of the VCM, addressing many of the aforementioned transparency, traceability, and GHG emission reduction or removal verification issues.

[15] https://medium.com/rwa-world/tokenization-taxonomy-esg-part-3-carbon-credits-94485d211d7d

B. Integrating DLT with Carbon Market Standards: Addressing Key Challenges in VCM

DLT can play a critical role in supporting the creation of a more reliable VCM by integrating with the standards already in place. By ensuring that emission removal meets predefined criteria - such as additionality, permanence, and third-party verification - DLT can bring greater integrity to carbon credit transactions, supporting the scale and credibility needed for meaningful climate impact.

In the context of carbon credits, tokenization provides a transparent, verifiable, and easily transferable digital representation of carbon offsets. This form of digitization enables several key advantages for the carbon market:

1. **Enhanced transparency and traceability** – Every transaction involving tokenized carbon credits is recorded on a DLT, creating an immutable record. This ensures that carbon credits can **be traced from their creation through to retirement**, significantly reducing the risks of fraud, double counting, or false reporting.

   In so doing, purchasers may have access to real-time insights into the lifecycle of a carbon credit, tokens act as data carriers and can deliver information without reporting delays, from the projects and also from independent verification sources using oracles. This functionality would increase market confidence. Furthermore, leveraging **blockchain provenance** allows purchasers to verify the environmental integrity of each carbon credit, ensuring that each token represents a legitimate reduction or removal of emissions.

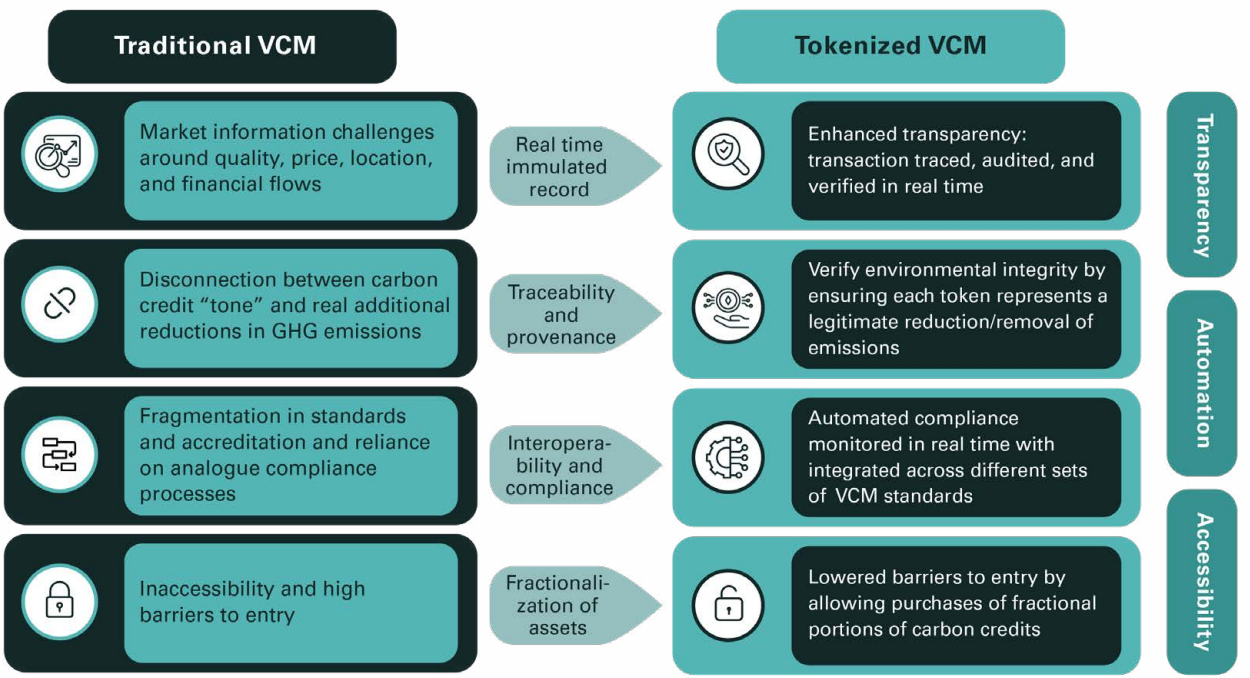


Figure 2 - Efficiencies Realized through DLT and Tokenization

The significance of this technological feature of in terms of **ensuring positive environmental impact** cannot be understated. Every carbon credit can be associated with verifiable data about its environmental impact, by embedding data about the credit's source, project validity, and verification status, ensuring that buyers are investing in genuine environmental outcomes.

2. **Accessibility** – Tokenization has the potential to improve accessibility in carbon markets by lowering barriers to entry and improving the user experience for smaller buyers. Currently, the process of creating carbon credits can be extremely expensive, requiring substantial capital and the buying carbon credits can be opaque. It is suggested that increased access will help drive liquidity in carbon markets, allowing more diverse participants to engage in the creation of carbon credits as well as the buying and, where relevant, the trading of carbon credits.

   Often individuals or smaller companies would like to purchase carbon credits to reduce their carbon footprint, but the barriers to entry to a carbon market registry and/or the quantity of tonnage available are too expensive. Larger companies, such as aggregators, can purchase carbon credits from multiple projects or purchase larger quantities of tonnage and "retire" them on behalf of these individuals or smaller companies. In so doing, the individuals or smaller companies have access to the markets without the expense or administrative burden of opening a registry

account. DLT can improve the tracking and traceability of this process, as well as reduce errors in the third party retirement process.

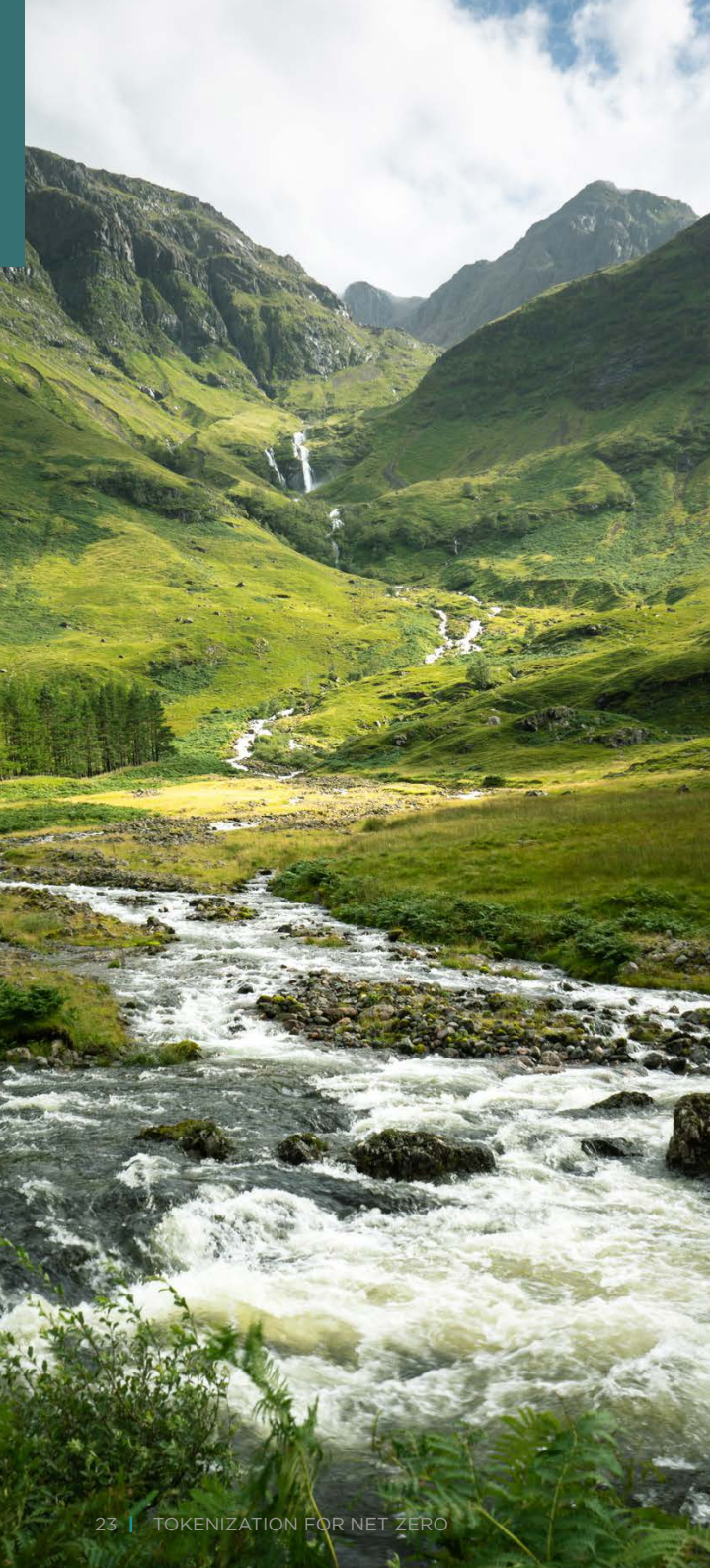
One feature of tokenization that may support better access and trading conditions is fractionalization. Fractionalization is the action of breaking larger assets down into smaller property units. This is not a process unique to blockchain, but the ability to easily and cheaply fractionalize using tokens that represent a portion of an asset or underlying pool means that the functionality is a key feature of the advantages of the technology. With carbon credits, fractionalization would allow purchasers to purchase fractional portions of carbon credits (representing a smaller unit rather than the standard one tonne of carbon dioxide), enabling smaller organizations and individuals to participate. This has interesting use cases in retail-facing applications (e.g. offsetting small-scale carbon emissions like airline tickets or consumer product purchases).

Fractionalization does have the potential to make things more complex in some respects though. For instance, if fractional tokenization has been carried out in relation to an underlying credit which itself has been issued in respect of a verified tonne of carbon emissions, retiring parts of that tonne for particular individual needs may require timing alignment to fully and properly retire the underlying credit. Fractional ownership may not always represent exactly the same rights as ownership of an entire asset (to provide a simple example from real estate, fractional ownership of 1sqm of leasehold interest in a commercial building does not give the owner the right to occupy that 1sqm, whereas ownership of the entire leasehold generally does entail rights to occupy).

Additionally, managing fractionalized credits in a decentralized environment requires a robust framework to ensure ongoing integrity and to protect buyers. As a result, certain legal and operational hurdles need to be addressed before the potential of fractional ownership can be fully realized in driving accessibility and liquidity in the carbon market.

3. **Smart contracts for automated compliance** – Smart contracts - self-executing contracts with terms directly written into code - can automate key processes such as GHG emissions verification, certification, and compliance with carbon standards. This automation ensures that carbon credits meet predefined criteria (such as additionality and permanence) and can pre-programme automatic retirement once used by a buyer. Transparent evidence of chains of transfer, effecting token “freezing” operations and providing for automated red flags in situations where compliance factors (like reporting standards) are not satisfied, may be other benefits that can be delivered through smart contract technology. In providing these benefits, smart contracts can enhance both compliance status of credits (improving the overall quality of credits that are available) and improve market confidence.

4. **Enhanced trading efficiency and capital mobility** – DLT can also facilitate additional financial functionality using carbon credits, adding new layers of market liquidity and enhancing overall demand. For example, tokenization can facilitate efficient secondary trading (including from an access, speed and per-transaction cost perspective) can support structures where tokenized credits act as collateral in financial transactions, adding a new layer of usability, and potentially also support the building of other



financial products on top of carbon credits (like asset-backed offerings and index-linked products), all of which will improve the range of offerings and flexibility for buyers, encouraging greater participating and scaling.

5. **Integrating token taxonomy** – Considerable work has been done in the last few years on token taxonomy and the categorization of tokens to enable participants the token space to have a shared core understanding about the nature of the tokens they are creating, buying, selling and how they may be regulated, taxed etc. as a result of dealing with them.

   In relation to basic shared understanding concerning token identification, the Commodity Futures Trading Commission's Global Markets Advisory Council for Digital Assets Markets (CFTC GMAC DAM) Subcommittee published the "Digital Assets Classification Approach and Taxonomy" in March 2024.[16] This taxonomy was developed through a consensus-driven approach, engaging digital asset ecosystem stakeholders, and is now widely considered the 'benchmark' taxonomy in the digital assets ecosystem to classify assets and the functions they serve in digital asset markets[17].

   In addition, standard terms of dealing are starting to come into existence for tokenized securities, for example through the ICMA DLT Bond work which includes "digital bond data taxonomy" amongst other things, the ISDA "digital assets definitions" (standard terms for use in trading digital asset derivatives) and the ISLA "digital assets annex" (standard terms supporting the use of digital assets in repurchase agreements (repo) trades). For tokenized carbon credits, being able to take advantage of the significant work that has been done on the financial side, leveraging the increasingly shared concepts, trading norms and market standards, would be of benefit, particularly from the perspective of creating trading scale and liquidity in the carbon credits themselves.

[16] https://www.cftc.gov/media/10321/CFTC_GMAC_DAM_Classification_Approach_and_Taxonomy_for_Digital_Assets_030624/download

[17] https://www.cftc.gov/media/10321/CFTC_GMAC_DAM_Classification_Approach_and_Taxonomy_for_Digital_Assets_030624/download

C. Applying Financial Services Infrastructure to VCMs

One approach to addressing VCM challenges has been to adapt established financial services infrastructure and principles to the market, as seen in Case Study 2: The Northern Trust Carbon Ecosystem™ which has gone someway to bringing to market solutions that address some of these challenges. Namely, it illustrates how institutional-grade solutions could enhance the transparency and efficiency of voluntary carbon credit transactions.

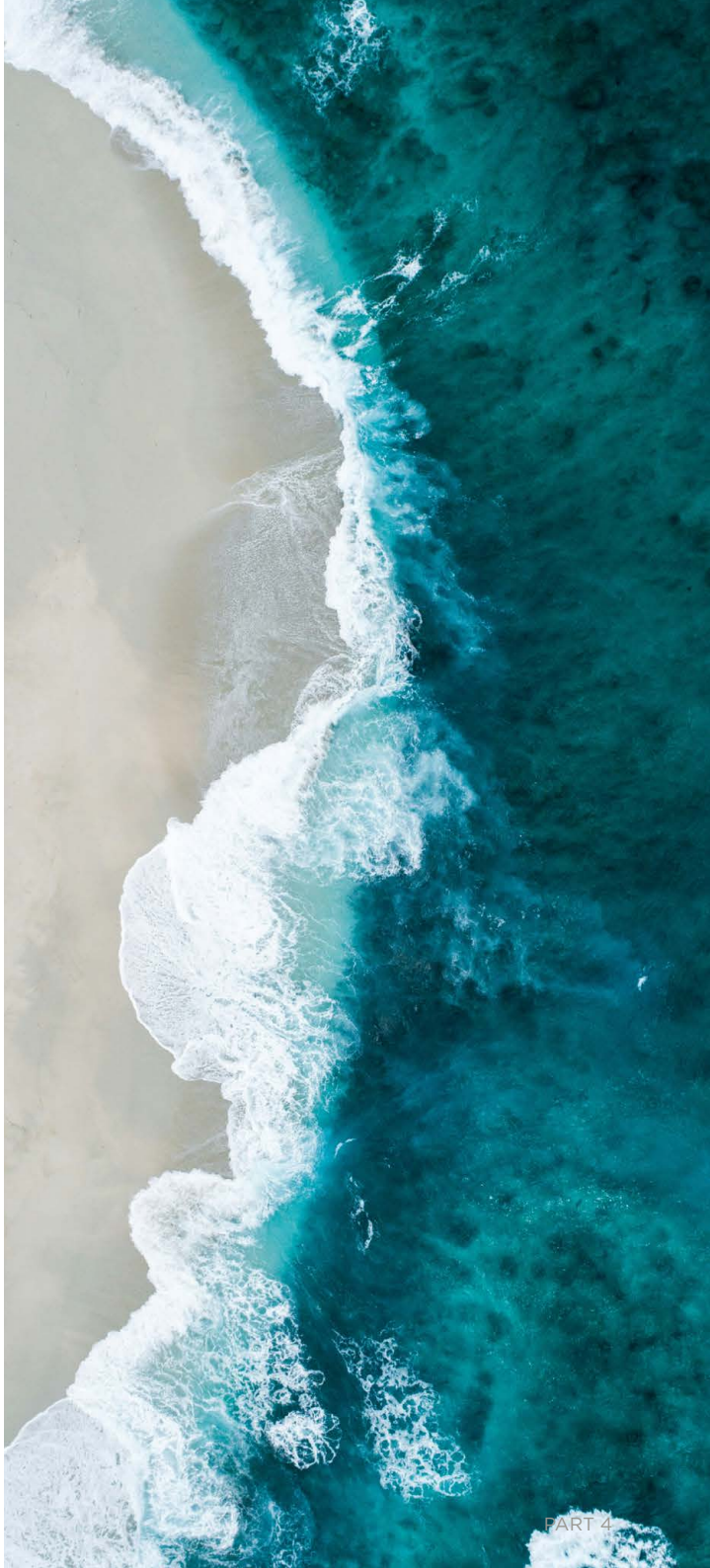
Key focus areas for solutions include:

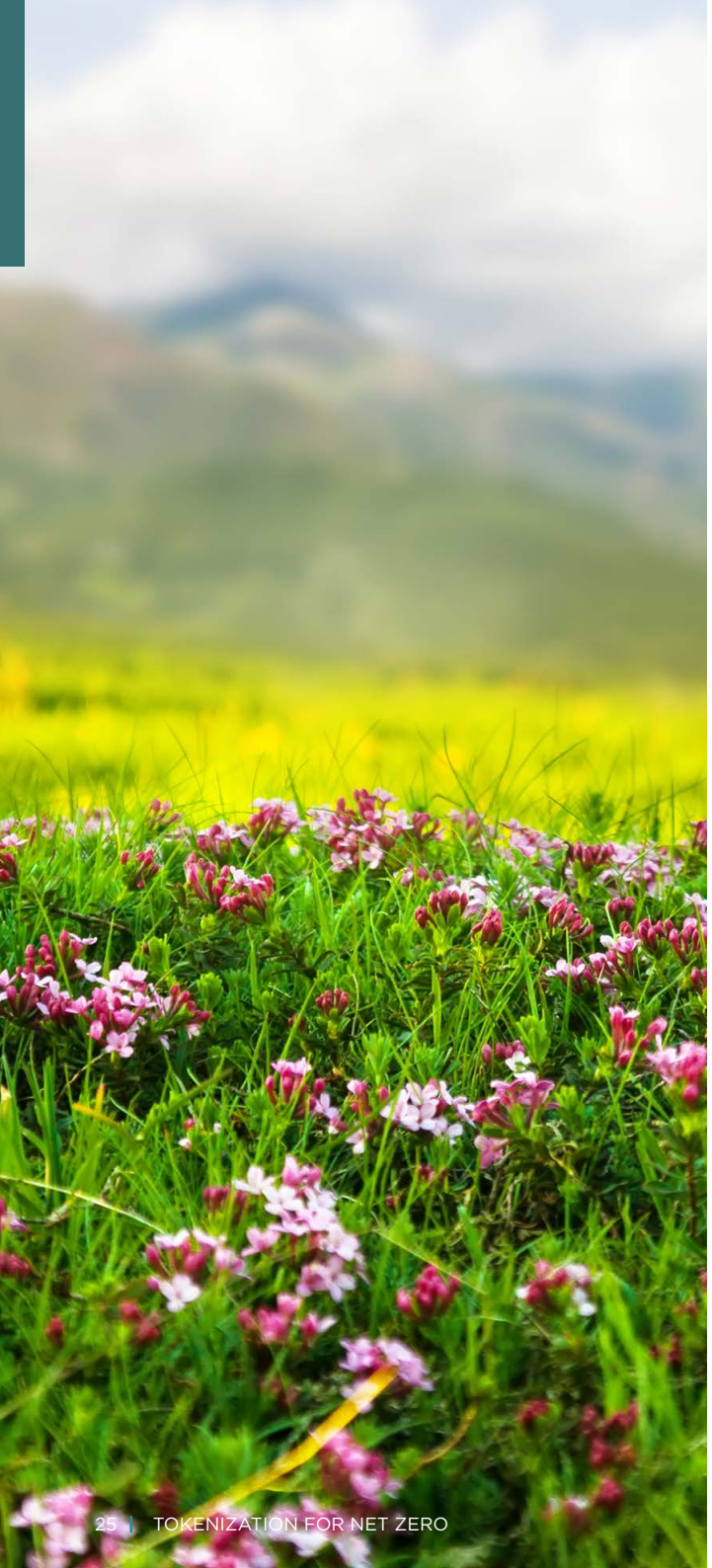
- **Automated lifecycle management:** Blockchain technology can provide systematic management of carbon credits throughout their lifecycle. By automating processes such as validation, verification, and retirement, this approach reduces manual errors and operational inefficiencies while supporting market confidence.

- **Integrated transparency mechanisms:** Integrating digital infrastructure enables project developers and institutional buyers to connect directly, providing greater visibility into credit provenance. This includes verified project details and transaction records, fostering trust and facilitating informed decision-making.

- **Building on financial services infrastructure:** By applying proven concepts from the financial services sector, such as secure transaction platforms and automated compliance workflows, this approach offers a model for addressing systemic issues in VCMs, including market fragmentation and lack of price transparency.

Leveraging financial services infrastructure can serve as a key enabler in address challenges such as transparency, traceability, and accessibility within VCMs.





D. Barriers to Carbon Credit Tokenization

Despite the promising potential of tokenization to transform carbon markets by increasing transparency, efficiency, and accessibility, several barriers to adoption must be addressed to ensure successful implementation and market acceptance. These challenges revolve around issues of standards, quality assurance, verification, and trust, which remain critical to the market's long-term integrity.

1. **Trust and integrity in the VCM** - One of the primary challenges is that tokenization alone does not resolve the longstanding issues of standards and quality assurance that exist within the voluntary carbon credit markets. Many of these markets suffer from inconsistencies in credit quality, making it difficult for participants to assess integrity and reliability.

   There are currently two main user journeys in the carbon credit market: **the buy-to-retire journey**, where buyers purchase credits to offset emissions, and the **buy-to-discover journey**, where participants speculate on price movements. Each of these journeys requires confidence in the underlying standards that ensure carbon credit quality and project integrity. For tokenization to succeed, it must enhance **confidence for both types of participants** by ensuring that every credit is tied to a verified and trustworthy project.

   Tokenization can improve transparency, but it cannot eliminate the inherent risks associated with fraudulent projects or poorly verified credits. Building trust and maintaining the **integrity of the market** require robust measures beyond tokenization, including greater enforcement of **standards** and **quality control** across both voluntary and compliance carbon markets.

2. **Market depth, liquidity, and credit quality** – Lack of fungibility is another ongoing challenge in VCM – in other words, one credit which ostensibly represents **one tonne of carbon is not necessarily equal to another**, despite being assigned the same nominal value. This is because buyers care about other factors, including the quality of the project, the country of origin, and the sector in which the carbon reduction or removal occurred. This may result for instance in a carbon credit from a high-quality reforestation project in one country being valued more highly than a credit from a less verified or lower-quality project in another. Although they supposedly represent the same amount of GHG emissions, their specifics which buyers attribute value to, render them not perfectly fungible.

   This lack of fungibility has contributed to the **fragmentation of the market**, with higher-quality credits often bypassing open markets due to persistent demand from premium buyers. As a result, **lower-quality credits dominate market trades**, primarily for **price discovery purposes**.

   Tokenization aims to **bring higher-quality credits back into circulation** by improving transparency and standardization, but it is crucial that this process does not lead to a race to the bottom where **aggregated products** are offered, which end up being priced based on the lowest-quality credits in a basket.

   In the EU, the **Carbon Border Adjustment Mechanism (CBAM)**[18] further complicates matters, as in domestic markets carbon credit price becomes a key driver, while the quality of credits may take a backseat. Exporting countries might set up domestic carbon markets to retain value rather than pay into the EU ETS. This would

allow them to domestically retain the value that would otherwise have to be paid to the EU ETS, if for no other reason than reducing the current account deficit (exporters using the EU ETS to meet the requirement would receive the purchase price minus the embedded carbon cost in both scenarios). In such cases, the price of domestic carbon credits becomes a tool for economic gain, with less regard for credit quality.

3. **Transparency and fraud prevention** – As described in Point 1, past instances of **fraudulent projects** have weakened confidence in the VCM and measures to help rebuild that confidence are needed and **robust transparency mechanisms** can support this. Tokenization alone can help by providing an immutable record of each credit's lifecycle, from creation to retirement, but this transparency must be coupled with stringent verification methods. **Transparency alone does not guarantee integrity**; it must be supported by **rigorous oversight** and **data verification processes** to prevent fraud. As tokenized credits become a larger part of carbon markets, ensuring **real-time access to verification data** and project details will be critical in rebuilding trust among stakeholders and supporting broader trust and integrity in VCM.

4. **Verification complexity** - The **ease and simplicity of verification** remain crucial factors for gaining market confidence. Tokenization provides a unique opportunity to introduce **on-chain verification mechanisms**, where the verification of GHG emissions and their underlying projects can be continuously monitored and audited. However, verification processes need to be **standardized** to ensure that all participants, regardless of technical expertise, can easily assess the validity of a carbon credit. Moreover, there is a need to develop **enriched data schemas** for tokens that can offer diverse verification methods (e.g., on-chain and off-chain sources), giving stakeholders more confidence in the reliability of each credit. The **credibility of verifying parties** is essential to establishing this trust, and these entities must be recognized as neutral, reliable, and transparent.

5. **Synchronized records and data integrity** – Data fragmentation is a challenge in today's VCM. In the long-term, the holistic digitization of this market may solve for some of this fragmentation (notwithstanding interoperability challenges discussed further in point 6). In the meantime, the prospect of a dual system – with both natively and non-natively digitized markets attempting to operate synchronously – may compound this fragmentation.

   Market participants are often required to maintain **mirror records** of carbon credits in both systems. The lack of real-time synchronization between these ledgers can lead to **discrepancies in ownership records**, potentially undermining the advantages of tokenization. Ensuring that the blockchain ledger and the traditional registry accurately reflect one another in real time is essential to maintaining investor confidence and avoiding disputes over ownership. This requires enhanced collaboration between regulators, standard-setting bodies, and blockchain platforms to develop a **seamless integration** between on-chain and off-chain systems.

6. **Interoperability challenges** – Interoperability – or connectivity – within the VCM is a significant challenge which is potentially layered on top of tokenization. There is currently a lack of interoperability between carbon credits that are held in different traditional registries and there are further interoperability challenges arising from different blockchains being used to tokenize credits.

   This is a common challenge amongst tokenized real-world assets generally, and adds another layer of complexity on top of the existing issues in the sector, where fragmented standards already make it difficult to compare credits. Tokenization could potentially help to address these challenges by providing a **standardized digital layer across registries**, but this solution is **contingent on creating interoperable platforms**. Without seamless integration between different carbon markets, price discovery and market liquidity will remain constrained.

While tokenization presents a path forward for VCM, addressing these ongoing challenges is essential to unlocking its full potential. The success of carbon credit tokenization depends on the establishment of robust, transparent, and synchronized systems that reinforce trust in the market. Building confidence through standards, verification, and data integrity will be key to ensuring that tokenized carbon credits can deliver on their promise of greater transparency, liquidity, and accessibility. ■

[18] The EU Carbon Border Adjustment Mechanism Regulation, which entered into force on 17 May 2023 and will come into effect on 1 October 2023, is, therefore, designed to counter the risk of carbon leakage and operates by imposing a charge on the embedded carbon content of certain imports that is equal to the charge imposed on domestic goods under the ETS, with adjustments being made to this charge to take into account any mandatory carbon prices in the exporting country."

PART 5
CASE STUDIES

Standards Spotlight: Data standardization and integration with LEIs/vLEIs

To support the better integration and synchronization in VCM across traditional and tokenized markets, standards are critical. In the context of financial services, many technical standards are helping create bridges between traditional finance and the ecosystem of digital assets. The Legal Entity Identifier (LEI) and verifiable LEI (vLEI) are examples of such standards.[19]

As described by the Global LEI Foundation, the LEI – based on the ISO 17442 standard developed - connects key reference information that enables clear and unique identification of legal entities participating in financial transactions and other official interactions. Each LEI contains information about an entity's ownership structure. In this way, the LEI answers the questions of 'who is who' and 'who owns whom'. Simply put, the publicly available LEI data pool is a global directory, which greatly enhances transparency in the global marketplace.[20]

More recently, GLEIF has developed the vLEI which serves as a digitized organizational identity to meet the global need for automated authentication and verification of legal entities across a range of industries – in other words, the secure digital counterpart of a conventional LEI.

In the context of tokenized carbon credits, LEIs and vLEIs could help underpin some of the standards needed to better support transparency and synchronicity across VCM and the tokenized carbon credit ecosystem.

With respect to better enabling transparency, LEIs can verify the identity of entities across the credit lifecycle, such as project developers, verifiers, and buyers, across multiple platforms and chains. vLEI's platform-agnostic, verifiable credentials ensure each credit's data is anchored to recognized entities, providing consistent transparency and trust in credit provenance regardless of the blockchain or registry in use.

LEIs can also authenticate smaller buyers' identities across platforms, enhancing accessibility while reducing fraud risk. As a blockchain-agnostic standard, vLEI allows decentralized credentials to securely represent participant identities in both centralized and decentralized settings, facilitating participation and compliance across diverse trading ecosystems.

To support better automated compliance, LEIs serve as standardized, platform-agnostic identifiers within smart contracts, verifying identities during compliance checks across blockchains. vLEI credentials, compatible with various DLT ecosystems, enable real-time, verifiable adherence to standards, ensuring automation of compliance and trust irrespective of the platform.

The ongoing challenges in carbon credit tokenization highlight the critical role of robust standards in enhancing trust, transparency, and interoperability within the voluntary carbon market (VCM).

LEIs and vLEIs can serve as a step forward in addressing these challenges by enabling a unified framework for identity verification and compliance across both traditional and tokenized ecosystems. By anchoring data integrity and authentication to globally recognized identifiers, these standards reinforce the market's credibility, reduce fraud risks, and foster greater confidence among stakeholders.

This integration with traditional market standards helps demonstrate how existing standards can be adapted to the unique complexities of tokenized markets, creating bridges that ensure seamless synchronization between on-chain and off-chain systems.

There is also recent precedent for attaching ISINs to carbon credits[21]. These types of initiatives are helpful in relation to promoting standardization and liquidity, as well as adopting best practices from traditional financial markets.

As VCM continue to evolve, incorporating such standards will not only mitigate risks associated with fragmentation and verification complexity but also position the market for scalable growth.

[19] https://www.gdf.io/wp-content/uploads/2020/12/GDFGLEIF_PartnershipAnnouncement_160724_FINAL.pdf
[20] https://www.gleif.org/en/about-lei/introducing-the-legal-entity-identifier-lei
[21] Powering Carbon Finance with ISIN, Blockchain, and Real-Asset-Backed Solutions for Trust and Transparency - Energy Industry Today - EIN Presswire

Case Study 1: Tokenovate and LandCarbon

One case study of blockchain as a solution to the current challenges in the traditional market, as well as blockchain's critical role in integrating existing standards, is Tokenovate's collaboration with LandCarbon.

LandCarbon, a project focused on restoring and managing peatlands in Scotland under the peatland code, aimed to mitigate methane emissions by re-heathering and re-flooding degraded peat bogs.

Tokenovate is developing an optimized web portal and software platform. The platform supports the origination and classification of carbon projects in line with standard methodologies, such as ICVCM. This creates a consistent and verifiable golden record of project data for each credit over its lifetime, allowing project owners and developers to maximize the value of their carbon assets and credits.

The approach begins with establishing a robust data structure essential for tokenization. This involves integrating various datasets through a data science programne that incorporates machine learning. Key datasets include geospatial data for precise location identification and LEIs to ensure each asset is uniquely identified. This data integration aims to prevent issues such as double counting and double spending of carbon credits, which have historically plagued the carbon market.

Carbon credits generated in respect of these projects can then be issued via the Tokenovate platform in tokenized form. This is done in accordance with applicable legal and regulatory standards, increasing legal certainty and ensuring robust enforceability of contractual rights and obligations.

Specifically, the tokenized carbon credits themselves are structured as bearer instruments, adhering to legal principles that emphasize ownership rights and enrich them with additional quality validation data (legal entity, geospatial data and ICVCM principles). This legal framework ensures that the tokenized carbon credits represent tangible assets and are protected by the private-public key relationship typical of blockchain technology. This setup facilitates trading through smart contracts, which are programmed to manage the issuance, distribution, and trading of tokenized carbon credits securely and transparently. As such, what the purchaser is acquiring, then, is the claim contract, which is the right to the underlying bearer asset.

This contract specifies the rights associated with each tokenized carbon credit, including future vintage releases of carbon credits generated by ongoing restoration efforts. This feature allows buyers to acquire tokenized carbon credits with confidence, knowing they are purchasing not just current assets but also future emissions reductions tied to the project's ongoing performance.

From a governance perspective, adherence to standards such as the ICVCM principles ensures that project developers like Land Carbon operate with transparency and accountability. Under the ICVM principles, a high integrity carbon asset is denoted by having a 40+ year programme — in other words, the project commits to long-term emission reduction goals, thus enhancing the credibility and value of tokenized assets over time.

By integrating advanced data analytics, legal frameworks, and smart contract technology, the approach aims to enhance market efficiency and reduce fraud risks. Furthermore, the blockchain ensures that the provenance of each token and its relationship with the underlying project data is maintained, providing a transparent and traceable history of ownership and transactions. In turn, this builds trust among stakeholders, thereby supporting the sustainable growth of the tokenized asset market.

Looking ahead, Tokenovate's platform provides a life-cycle management engine, using blockchain-powered smart contracts capable of automating post-trade processes, asset servicing, and reporting. This will become increasingly important as more sophisticated financing products (e.g., swaps and forwards) emerge within the carbon markets.

Case Study 2:
The Northern Trust Carbon Ecosystem™

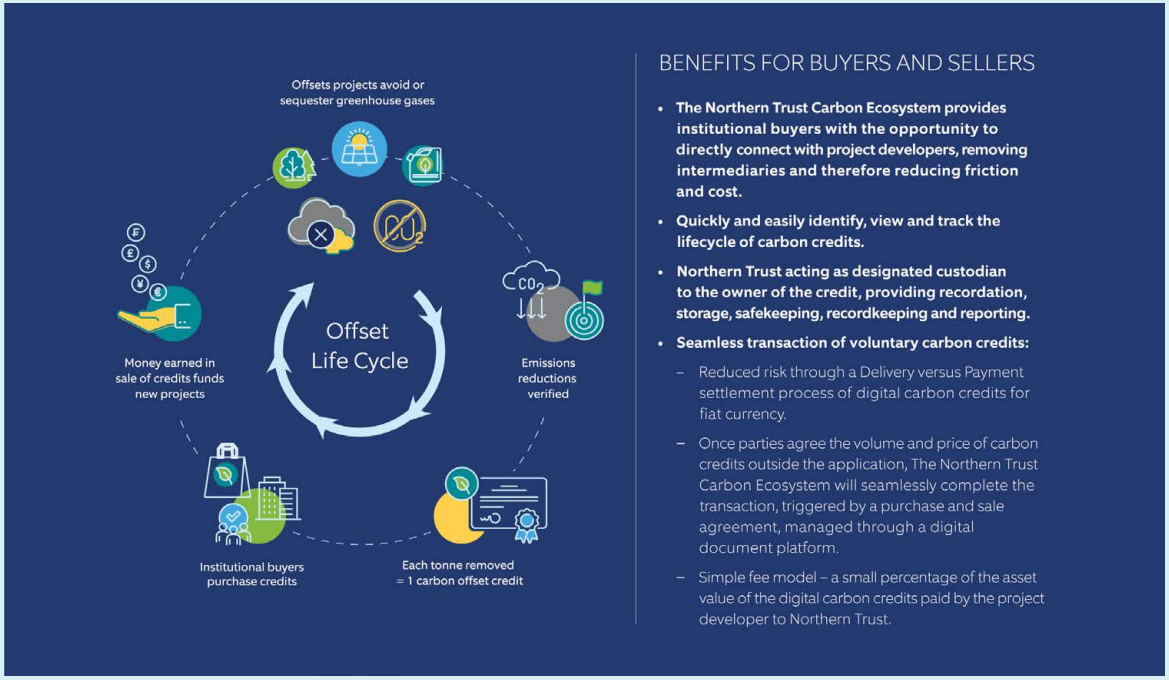
The Northern Trust Carbon Ecosystem supports the growing interest in the VCM by providing an end-to end digital lifecycle management capability for digital voluntary carbon credits.

Despite some automation and digitization in the VCM over the last few years, this market has been characterized by isolated products and solutions. Many of the processes are manual, offering low levels of transparency to institutional buyers of verified carbon credits.

The Northern Trust Carbon Ecosystem helps to address these issues by providing an automated ecosystem, giving carbon avoidance and removal project developers and institutional buyers confidence and transparency through the lifecycle of their voluntary carbon credit transactions. Utilizing custom designed, private ledger digital blockchain technology, it provides a digital platform for project developers and buyers to explore, transact and retire voluntary carbon credits.

An Ever-Growing Focus on Carbon Footprints

Pressure on institutions to understand and measure the environmental impact of their operations continues to intensify via regulatory, client and shareholder pressure. This requires institutions to commit more time, effort and resources to understanding the impact of climate change and Environmental, Social and Governance (ESG) factors in relation to their businesses. The initiative is not designed to negate the need for



Source: NT Carbon Ecosystem Service Agreement April 2025

institutions to understand and reduce their carbon footprint. This development acknowledges that carbon credits/offsets are a way to take immediate action while on their journey to reduce overall GHG emissions.

Solutions for the Entire Voluntary Carbon Credit Lifecycle

The Northern Trust Carbon Ecosystem connects institutional buyers with carbon credit project developers who are focused on solutions to reduce GHGs including carbon dioxide, supporting carbon credit projects:

- Project developers can record validated and verified project credits and engage directly with institutional buyers to connect and explore specific details of the carbon credits they would like to transact.
- Systematic management of selling carbon credits, reducing manual risks.
- Supported by institutional grade digital assets infrastructure and powered by Northern Trust Matrix Zenith, Northern Trust's digital assets platform.

The terms of each transaction are captured in a purchase and sale agreement managed through a digital document platform with the movement of carbon credits and cash automatically managed by The Northern Trust Carbon Ecosystem in accordance with the purchase and sale agreement, with support from a dedicated Northern Trust team.

High-Integrity Credits Onchain-Financing with Project Genesis 2.0

Led by the BIS Innovation Hub, Genesis 2.0 examines the use of blockchain and smart contracts to integrate digital carbon offsets with green bonds, enhancing transparency and accountability in financing green projects.

Genesis 2.0 introduces a new structure for green bonds, ones that are appended with mitigation outcome interests (MOIs). MOI's are carbon forward instruments that the bond issuer owes to the MOI holder. The bond's future repayment is made using carbon credits that are largely generated by activities financed by the original green bond. Pledging carbon credits as part of the green bond results in bond issuers obtaining cheaper funding for green investments. The green bond structure is appended with MOIs, which are repaid in mitigation outcome units (MOUs).

MOIs are an instrument of carbon unit indebtedness of a green bond issuer to the holders of the MOI. Future repayment on MOIs is made using MOUs. MOUs are units of GHG emissions reduction. Essentially, they are carbon credits recognized under international or national verification mechanisms compliant with the Paris Agreement. Hence, an MOI is a commitment to deliver units of GHG emission reduction attached to the bond. MOIs can be sold and traded immediately, separate from the bond issuance.

MOUs used to repay the MOI obligations need to be mainly generated by the assets or activities financed by the proceeds of the bond, and not bought from the carbon market. In exchange for an MOI, the bond pays a premium or provides the issuer with another type of economic benefit compared with its baseline source of financing.

The proposed structure strives to consider the greenness of the issuer's entire investment plan, such that MOUs generated by the assets or activities financed by the proceeds of the bond are first used to offset any climate performance gaps from other activities of the issuer financed after the issuance of the bond. Only the remaining MOUs can be used to repay the MOIs to the bond investor. ■

PART 6
CONCLUSION AND RECOMMENDATIONS

Recommendations

The VCM is at a crossroads. While it holds enormous potential to drive global decarbonization efforts, persistent challenges - ranging from market fragmentation and inconsistent standards to lack of transparency and high barriers to entry continue to threaten its integrity and scalability.

This report has explored the existing structural weaknesses within the VCM, highlighting the risks of greenwashing from lack of integrity and transparency, and the adverse effects of opaque pricing and misaligned verification standards. It also sheds light onto how emerging technologies including DLT and tokenization have emerged as promising tools to address many of these inefficiencies, offering greater transparency, efficiency, and accessibility.

However, technology alone will not be a panacea. For tokenized carbon markets to succeed, industry participants, regulators, and technology providers must coordinate efforts to establish robust governance frameworks and harmonized standards subject to clear globally coordinated supervision. This conclusion outlines a set of key recommendations to enhance market confidence, improve price discovery, and foster an efficient, scalable, and credible carbon credit market.

1. Establish a Unified and Standardized Market Framework that Supports Technological Innovation within VCM

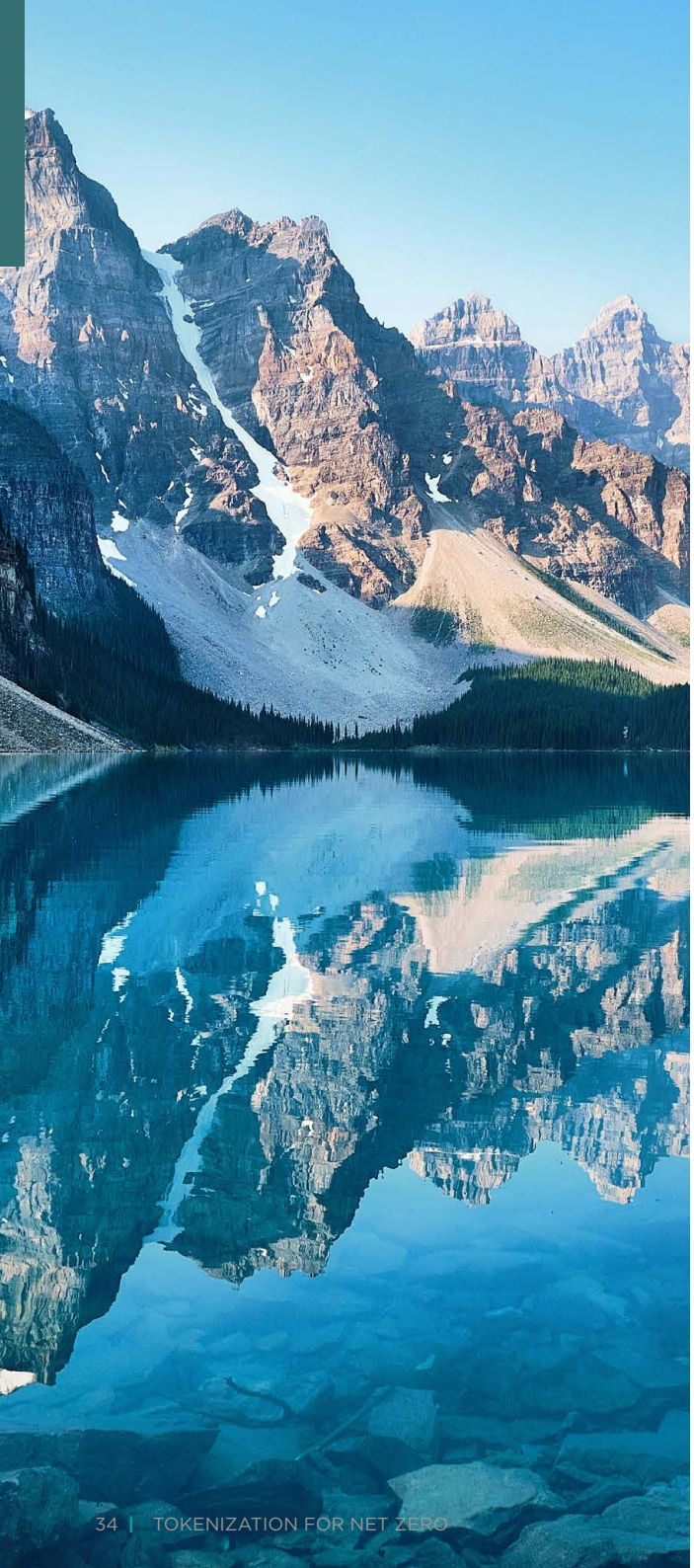
One of the most significant barriers to the scalability of the VCM is the lack of standardized rules for carbon credit verification, issuance, and trading which support technological solutions like carbon credit tokenization. The current landscape is fragmented, with multiple independent standards agencies applying differing methodologies which take different approaches to the accommodation of technological solutions. Many of these standards agencies do not recognize or support the trading of tokenized carbon credits amplifying the gap between traditional VCM and tokenized counterparts. A global standard-setting initiative for tokenized carbon credits – similar to those undertaken in financial markets for securities tokenization – should be developed to harmonize accreditation, verification, and compliance standards across both traditional and tokenized VCM.

Recommendation: Establish an industry-led working group with the support of regulators to develop a common accreditation and reporting framework for tokenized carbon credits, drawing on international best practices and work developed by global standard-setters like IOSCO.

2. Utilizing DLT to Improve Market Transparency and Price Discovery

The opaque nature of carbon credit pricing has led to significant information asymmetry, creating inefficiencies and distrust in the market. Buyers often struggle to differentiate between high and low quality credits, while bilateral trading mechanisms limit price transparency.

Recommendation: Enable carbon credit tokenization and recognize its validity in VCM to help to provide real-time price transparency, standardized data on credit quality, and transaction histories to the market.



3. Enhance Trust and Integrity Through Independent Verification and Auditable Digital Records

Greenwashing concerns and fraudulent credit issuance undermine market confidence. The principles of financial market regulation – including independent audits, robust KYC/AML mechanisms, and transparent ownership records – should be adopted and adapted to carbon credit markets.

Recommendation: Leverage DLT-based technologies and tokenization to embed verification data, independent audit trails, and third-party validation mechanisms directly into carbon credit transactions, enhancing certainty of provenance and full traceability from issuance to retirement.

4. Regulatory and Policy Support for Education and Innovation in Tokenized Carbon Markets

In financial markets, industry sandboxes have successfully enabled experimentation with tokenization models, allowing regulators to develop targeted legal frameworks that facilitate market growth while maintaining stability.

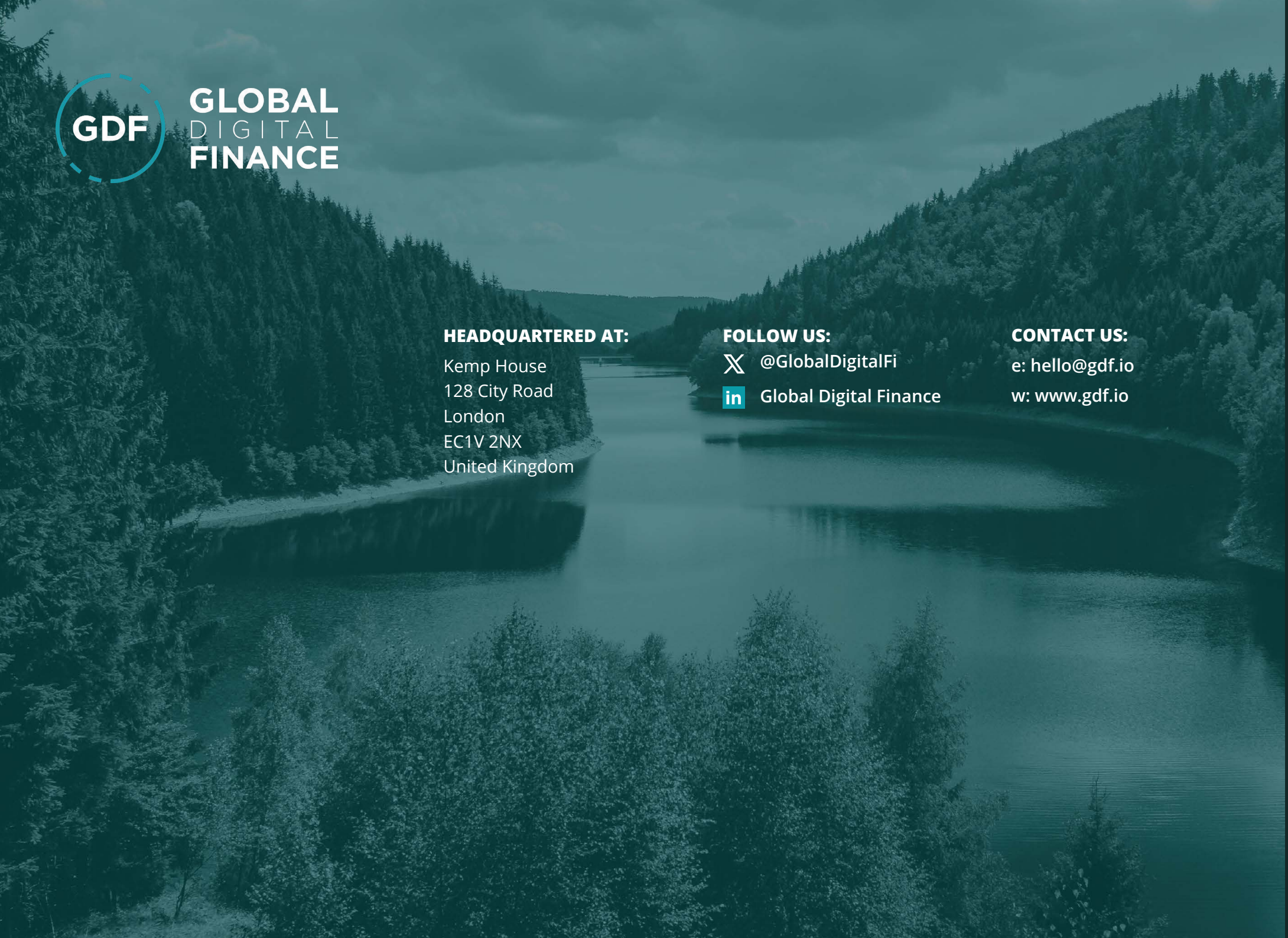
Recommendation: Consider introducing an industry-led sandbox for tokenized carbon markets (or introducing a focus theme into an existing sandbox structure), allowing market participants to test carbon credit tokenization models within a controlled environment. This could support process and procedure improvements, standards and market participant expectations alignment, and the identification and mitigation of risks, while fostering innovation. Capacity building across public and private sector as to how the potential efficiencies and improvements realized through technological innovation will be important too.

Conclusion

Supported by technological innovation, the VCM has a unique opportunity to fulfil its potential to evolve into a high-integrity, liquid, and widely accessible financial instrument market. However, without structural reforms, fragmentation, distrust, and inefficiencies will continue to limit its impact.

To achieve this vision, regulatory clarity, industry-wide cooperation, and robust technological integration must be prioritized. Carbon credit tokenization can increase transparency, enhance efficiency, and expand market participation, but stakeholder buy-in, policy alignment, and a focus on interoperability will be crucial for long-term success.

These recommendations put forth a starting point for market participants to assess who, how and what is required to support VCM transitioning into a mature, scalable, and trusted market, driving meaningful climate action while fostering economic growth and financial innovation. ■



GLOBAL DIGITAL FINANCE

HEADQUARTERED AT:

Kemp House
128 City Road
London
EC1V 2NX
United Kingdom

FOLLOW US:

@GlobalDigitalFi

Global Digital Finance

CONTACT US:

e: hello@gdf.io

w: www.gdf.io