Scaling Voluntary Carbon Markets Through Open Blockchain Platforms

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Abstract

The Voluntary Carbon Market (VCM) plays an important role in the fight against climate change. Open blockchain platforms can help channel capital from fast-growing digital economies towards project developers and environmental service providers, and enable more transparent and efficient carbon markets. This paper bridges the gap between the conventional VCM and the world of open blockchain platforms. We highlight key challenges and opportunities for further blockchain-carbon integration and provide recommendations for stakeholders both in the conventional VCM as well as the emerging blockchain-carbon sphere. The goal is to encourage effective integration while ensuring integrity in the broader VCM system.

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Introduction

The Voluntary Carbon Market (VCM) has enormous implications for the world's ability to stave off the worst effects of climate change.[3] Buyers and sellers trade in tons of carbon dioxide that are removed from the atmosphere or don't get emitted in the first place, providing for a market-based solution to compensate for hard-to-avoid emissions.

With the introduction of cryptocurrencies more than a decade ago, the high-flying world of blockchains, smart contracts, and decentralized finance (DeFi) seemed a world away from the relatively quiet and staid world of carbon offsetting. But in the last couple of years, these industries have started overlapping and integrating in ways that could have implications for all. In a sense, this integration is not surprising: carbon credits are brought into existence as entries in a carbon registry that are either held or transferred between account holders and retired for offset purposes. Tokens on a blockchain platform are 'minted' into existence as entries on a public ledger and are held or transferred between digital addresses or taken out of circulation ('burnt'). Carbon registries are interested in a verifiable, transparent, and tamper-proof handling of credits — problems for which blockchain platforms are designed to solve.[4]

This integration potentially has tremendous value. Offset buyers are typically limited to large corporations, and while the demand from this sector is fast-growing, it still leaves out individuals and communities of individuals. A blockchain integration would allow individual-level access to carbon credits, creating additional capital flow to project developers and emission-reduction measures. Recognizing this potential and following earlier research by the World Bank,[5] the International Emissions Trading Association (IETA) recently set up a task force on digital climate markets and issued a first set of recommendations on further market integration while ensuring integrity in the VCM.[6][7]

McKinsey recently identified challenges in scaling up the VCM and argued that the current VCM lacks liquidity and fails to generate reliable price signals for its market participants.[8] Integrating with open blockchain platforms could increase market transparency and liquidity, and generate valuable price information for stakeholders in the offset development supply chain. The composability of tokens and the open nature of blockchain platforms could allow creating markets with deep liquidity and with transparent and differentiated pricing, taking into account the heterogeneity of carbon credits. This would also be in line with the World Bank's proposed Climate Warehouse,[9] which aspires to link all carbon credit issuing authorities and registries under one platform.

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[3] We will refer simply to 'carbon markets', 'carbon credits', or 'offsets' throughout this whitepaper for readability purposes. We always refer only to the voluntary market, not to national or international compliance markets.

[4] More precisely blockchains are tamper-evident. Changes can be made to a blockchain (sybil/51% attack), but not without it being evident to observant network participants.

[5] World Bank Group, 2018, *Blockchain and Emerging Digital Technologies for Enhancing Post-2020 Climate Markets*

[6] IETA, 2022, *IETA Launches Task Group on Integrity in Digital Climate Markets*, https://www.ieta.org/page-18192/12286504.

[7] Carbon Pulse, 2022, *COMMENT: IETA Council Task Group on digital climate markets – Key findings and recommendations*, https://carbon-pulse.com/153786/.

[8] McKinsey, 2021, *A blueprint for scaling voluntary carbon markets to meet the climate challenge*, p. 5, 6.

[9] See https://www.theclimatewarehouse.org/. The Climate Warehouse initiative is part of the World Bank's Carbon Markets and Innovation unit.

The link between the carbon and blockchain worlds has generated headlines recently because of the actions of KlimaDAO, which reportedly accrued around 14 million tons of carbon offsets in 2021.[10] The goal has been to drive up the offset cost, thus encouraging more GHG-reduction projects. This triggered criticism from the conventional offset industry: The head of the Gold Standard registry commented on the anonymous nature of KlimaDAO,[11] while the Verra registry publicly distanced itself from blockchain market activities.[12] It's not surprising that the offset industry would be defensive, as carbon credits themselves have been controversial at times. Concerns around additionality and double-counting have been issues for years. This demonstrates that, while the blockchain and the offset communities have a lot of aligned interests, there are still challenges to overcome before the full potential can be unlocked.

This whitepaper aims to bridge the gap between the carbon and blockchain worlds and highlight some key challenges and opportunities around blockchain and carbon offsets, with the goal to bring more investment in—and faster acceleration towards—a low-carbon economy.[13] Our objective is to offer guidance for what could eventually be the 'rules of the road' for how blockchain technology can help support investments in climate mitigation without undermining them. The result, we hope, is that offset project developers, traders, users, investors, local and contiguous communities, and offset registries can 'sing from the same sheet of music' and ensure integrity in the whole system.

The paper covers the following topics:

- A brief overview of the voluntary carbon market;
- The different layers at which current blockchain market activities interact with carbon markets;
- The challenges of and opportunities from integrating carbon and blockchain markets; and
- Recommendations that can address specific concerns of many in the community

Background

Carbon markets and the path ahead

The global carbon market initially took off with the Kyoto Protocol. A voluntary offset market, patterned in part on the US Environmental Protection Agency's SO2 trading market to deal with acid rain, did exist prior to Kyoto. But the treaty, once ratified in 2005, set off a massive flow of investment into GHG reduction projects around the world. The driver was the Clean Development Mechanism (CDM), which established a system of cross-border emissions trading between developed countries (offset buyers that

[10] KlimaDAO, 2022, https://twitter.com/klimadao/status/1477650022573477893
[11] Cointelegraph, 2022, *KlimaDAO increases carbon offset stash by 50% in two months*, https://cointelegraph.com/news/klimadao-increases-carbon-offset-stash-by-50-in-two-months.
[12] Verra, 2021, *Verra Statement on Crypto Market Activities*, https://verra.org/statement-on-crypto/.
[13] This paper does not address the power requirements and associated emissions of blockchain technology itself, primarily because this is a non-issue with modern blockchain platforms. Blockchain platforms utilizing Proof-of-Stake (PoS) consensus mechanisms have a negligible carbon footprint compared to the popular and energy-hungry Proof-of-Work (PoW) platforms such as Bitcoin or Ethereum. In fact, modern PoS platforms such as Celo integrate carbon offsetting into their protocol design, making them not only energy-efficient but carbon net neutral on the protocol layer.

were required under Kyoto to lower their emissions) and developing countries (offset sellers). The system was 'regulated' by the CDM Executive Board, established under the UNFCCC. This board established the rules for the development of carbon offset methodologies or protocols. These methods had to be followed exactly in order to have the CDM board issue credits.

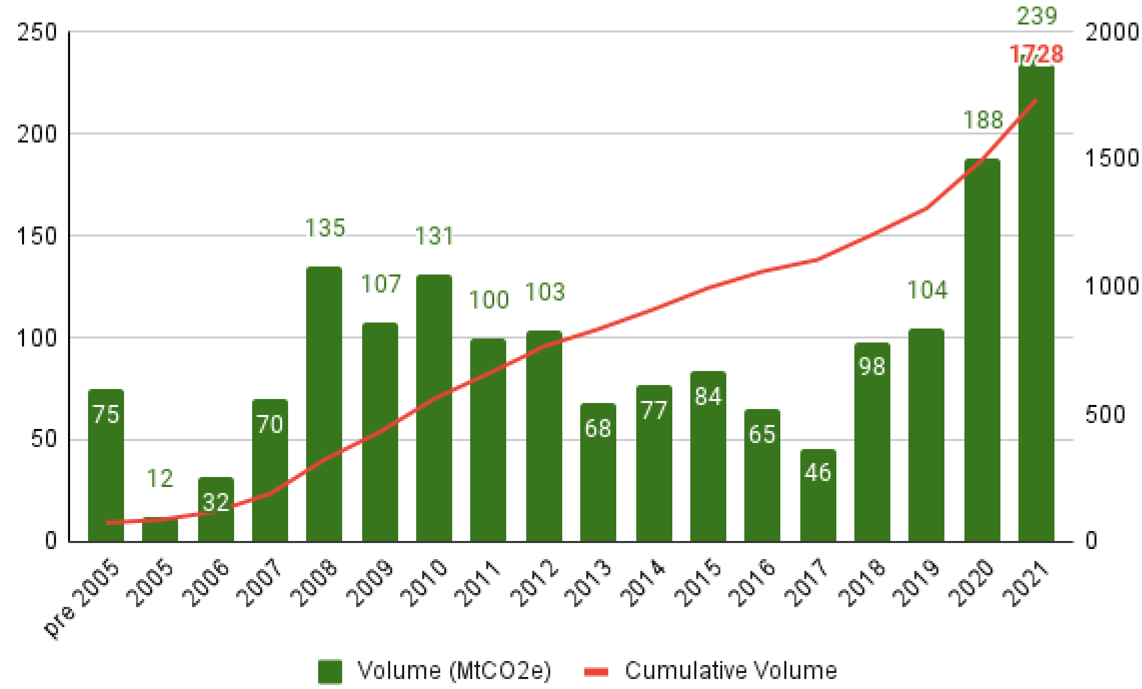
From 2005 to 2012 (when Kyoto expired), tens of billions of dollars flowed into offset projects, but the system fell apart, first because of the Great Recession and then because no international treaty replaced Kyoto. This collapsed global market was replaced by a small but growing voluntary market (e.g., corporations seeking offsets to become carbon neutral) and a fragmented system of regional compliance programs (Europe, California, Korea and others). Few of these regional programs are allowed to trade across jurisdictions, so the voluntary market is now the only truly global carbon market.

From 2012 to around 2017, the VCM was very quiet, with fewer buyers than sellers and low prices. Things began to change in 2018, and in the last 12 months, the market skyrocketed — doubling in volume in just one year. Perhaps most important in the graphs below is the steady rise in the average offset price (second chart). While the $6.78 average price may seem relatively low, that includes millions of lower-value credits.

The size of the VCM can be a challenge to quantify because the analyses are mostly based on surveys conducted by a single company called Ecosystems Marketplace. But its most recent survey states that the total market value of $473 million in 2020 was the highest annual value since 2012 and that the total market will likely exceed $1 billion in 2021.[14]

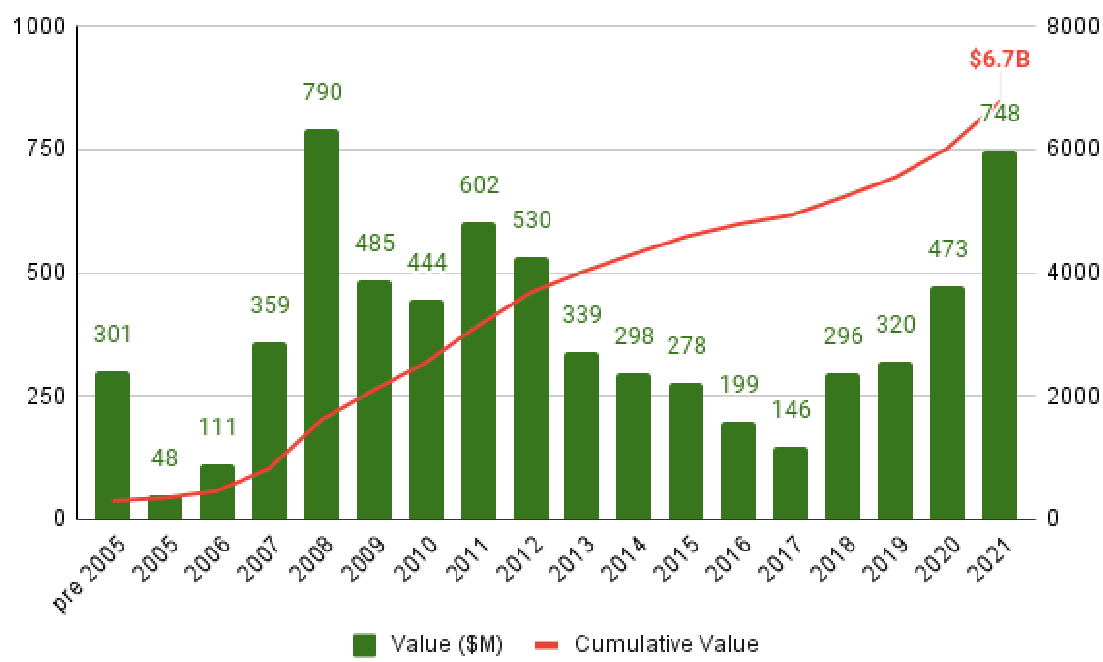
[14] Ecosystem Marketplace, 2021, Markets in Motion—State of the Voluntary Carbon Markets 2021, p. 3.

Market size by traded volumes (pre-2005 to Aug 2021)



Source: Ecosystem Marketplace, 2021, Markets in Motion—State of the Voluntary Carbon Markets 2021, p. 4. Includes Chicago Climate Exchange-traded offsets; 2021 includes values until 31 August.

Market size by traded value (pre-2005 to Aug 2021



Source: Ecosystem Marketplace, 2021, Markets in Motion—State of the Voluntary Carbon Markets 2021, p. 3. Includes Chicago Climate Exchange-traded offsets; 2021 includes values until 31 August.

When it comes to forecasting future demand, one of the best reports to date was published by University College London and Trove Research.[15] The researchers divided the market into three segments:

- Specific large-scale demand from European oil and gas companies
- The international aviation offsetting program, which started in 2021 (known as CORSIA)
- The corporate ESG market (companies seeking to become carbon neutral)

In the table below, we can see a potential range of offset demand by 2050, from 1.1 billion tons to 3.6 billion tons *per year*. For reference, the cumulative demand in the VCM from before 2005 through mid-2021 (as shown in the graph above) was 1.728 billion tons.

Offset Demand/Year (Million metric tons)

	2020	2030	2040	2050
EU oil & gas scope 3	-	100 - 200	200 - 410	310 - 620
CORSIA	-	60 - 150	160 - 400	270 - 640
Economy-wide scope 1 and 2	90	270 - 950	440 - 1,990	520 - 2,340
Total	**90**	**430 - 1,300**	**800 - 2,800**	**1,100 - 3,600**

Source: Trove Research, 2021, Future Demand, Supply and Prices for Voluntary Carbon Credits—Keeping the Balance, p.15.

This forecast in demand is encouraging but still insufficient to deal with the overall climate challenge. This demand only comes from corporations and not individual actors, who could spur even further demand. To operate in the conventional carbon offset world, one has to open an account on an established registry, such as the Gold Standard or Verra (the organization that operates the Verified Carbon Standard). Opening an account requires a know-your-customer (KYC) process and other steps that few, if any, individuals would complete themselves. So, while the forecasted demand from conventional corporate buyers is impressive, the digitization of economies around the world, including massive mainstream adoption of digital currencies, offers new opportunities for the expansion—and increasing inclusion—of carbon offset markets and activities.

Blockchain-carbon market integration

According to Coinmarketcap data, the total cryptocurrency market cap exceeded $2 trillion by the end of 2021[16] Only a small portion of that may be directed to carbon offsets, but the conclusion is clear: bringing the resources of open blockchain markets to bear could enable much more investment to the carbon finance industry as well as innovation utilizing blockchain technology. Before considering the

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[15] Trove Research, 2021, Future Demand, Supply and Prices for Voluntary Carbon Credits—Keeping the Balance.

[16] CoinMarketCap data, 2022, https://coinmarketcap.com/charts/.

mid-range and long-term potential, it is worth highlighting how the different layers of blockchain technology integrate with the VCM today.[17]

Layer 1: Registries and credit issuance

The first layer involves the issuance and creation of tokenized credits, and making them available to the broader blockchain ecosystem. One challenge is how to port science-based standards available on existing registries to public blockchain infrastructure. Early attempts at porting are underway with so-called 'carbon bridges'. The idea is to bridge off-chain credits already issued by incumbent registries on-chain. For example, when a project developer successfully lists a project on Verra and undergoes a third-party audit verifying those emission reductions, Verra issues a corresponding number of credits on its registry platform—each with individualized serial numbers—into the account set up by the project developer. Those Verified Carbon Units (VCUs) can then be transferred to a buyer's Verra registry account and either sold, banked, or retired. Bridging services build on top of these registries to create a tokenized representation of the off-chain VCUs.

Verra, Gold Standard and other established carbon credit registries have been developing and refining their processes for years — from protocols for quantifying the GHG reductions to detailed monitoring requirements and third-party verification. Most corporate carbon credit buyers will only buy credits from these registries because they value the rigor of the process. The 'carbon bridges' mentioned above build upon the credibility and scientific rigor of existing standards and registries, simply giving them new form for compatibility with rapidly emerging digital markets.

One challenge in carbon bridging is how to synchronize the off-chain registry with the on-chain token representation. Some carbon bridges tackle this problem by retiring the credit on the off-chain registry and linking it to a blockchain token, so that, at any single point in time, only one credit (either off-chain in the registry or on-chain as a token) exists.[18] Other bridging services follow a different approach, as credits are not retired in the off-chain registry, but rather held in a special custodial setup that aims to synchronize the off-chain and on-chain status of the credit (e.g., if the credit is retired on-chain, it is also retired off-chain and vice versa).[19] This allows users to continue transacting on the off-chain market, while at the same time having access to the on-chain market.

Another approach that has gained less traction to date is to launch blockchain-native credit standards.[20] So far, however, demand for such blockchain-native credits appears to be limited.

Layer 2: Market infrastructure and innovation

The second layer consists of the carbon market infrastructure that is built around tokenized carbon credits. One challenge in the VCM is that no two projects are the same—they can differ in methodology,

[17] Blockchain technology has further potential applications throughout the carbon credit life cycle, e.g. in carbon monitoring, reporting and verification (MRV). See, for example, Gold Standard's Digital MRV (https://www.goldstandard.org/our-story/digitising-mrv) and pilot projects of the Climate Ledger Initiative (https://www.climateledger.org/). While MRV use cases can be thought of as 'Layer 0' in the context of this paper, those use cases won't be discussed in the following.
[18] See, for example, Toucan Protocol (https://toucan.earth/) and, similarly, Moss.Earth (https://moss.earth/).
[19] See, for example, Flow Carbon (https://www.flowcarbon.com/).
[20] See, for example, Nori (https://nori.com/).

geography, associated co-benefits, etc. This makes pricing of credits difficult, which is why in traditional offset markets pricing is often opaque and illiquid.[21] Prices are usually the result of bilateral negotiation between a project developer/wholesaler and an institutional customer. Blockchain technology can begin to ameliorate these shortcomings by providing market infrastructure that improves tradability, traceability, and liquidity.

Tokenizing carbon credits provides for the possibility to pool different credits together based on some common characteristics (e.g., a common vintage threshold or common methodologies) and to issue index credit tokens that represent the average credit in those pools.[22] This makes rather non-interchangeable ('non-fungible' in blockchain lingo) credits both liquid and comparable (fungible) and thus opens up the possibility for deeper liquid markets.

It also allows for more differentiated pricing because multiple carbon pools can co-exist in parallel, providing valuable price signals to market participants. For example, dynamic carbon pools with a trailing vintage threshold (e.g. vintages that are at most five years old) could provide for more up-to-date market prices, as they would not be influenced by prices of credits that 'sit on the shelf' for a long period of time. This would in turn improve price signaling and attract more participants, including crucial project developers whose future projects might not otherwise be viable.

Layer 3: Market participants and credit demand

The third layer concerns the demand for carbon credits. Blockchain integration expands the use cases of carbon credits beyond traditional corporate offsets. Carbon token projects typically have an offset mechanism in which a credit token is taken out of circulation ('burnt'), similar to the retiring process on traditional registries. The advantage to traditional registries, however, is the ability of tokens to interact with automated smart contracts, which allows integration of carbon credits in more complex and innovative use cases.

Decentralized finance ('DeFi') protocols use tokenized carbon credits, for example, as building blocks in their applications. KlimaDAO has incentivized the transfer of carbon credit tokens into its treasury in exchange for Klima tokens. This, according to KlimaDAO, should generate additional demand for off-chain carbon credits as it pushes up the floor price, making a wider array of offset and removal projects viable. As of this writing, more than 17 million carbon credits– worth more than $100m– have been transferred to the KlimaDAO treasury.[23]

Decentralized stable asset protocols started adding tokenized carbon credits to their reserve holdings to generate positive environmental impact. The stable assets that are native to the Celo blockchain are, for

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[21] See also McKinsey, 2021, A blueprint for scaling voluntary carbon markets to meet the climate challenge, p. 5, 6.

[22] For example, Toucan's Base Carbon Tonne (BCT) token represents a blend of different carbon credits with vintage 2008 onwards. The Nature Carbon Tonne (NCT) token is more curated and only represents nature-based credits with vintage 2012 onwards. See Toucan website, 2022, *Pool Acceptance Criteria*, https://docs.toucan.earth/protocol/pool/pool-acceptance-criteria. Toucan argues that its Base Carbon Tonne (BCT) token serves as a public baseline for the broader carbon market and is used by traders in the traditional VCM to determine floor prices. See Toucan, 2022, *Expediting bridge approvals, BCT quality and selective redemptions*, https://blog.toucan.earth/improving-bridge-approvals/.

[23] See KlimaDAO website, 2022, https://www.klimadao.finance/.

example, backed by a reserve of various digital assets, including an allocation of carbon credit tokens.[24] This creates a mechanism, in which when demand for stable assets grows, the reserve purchases more and more credits, creating a continuous capital flow to project developers and environmental service providers. As of this writing, the reserve holds assets worth around $600m and has a target allocation of 0.5% towards tokenized carbon credits. The Celo community has the vision to expand this allocation substantially over the coming years,[25] which would require a healthy and liquid tokenized carbon credit market.

The composability and programmability of tokens opens up the possibility for new use cases. DeFi innovation can lead to innovative climate finance solutions that are built around carbon credits, involving and incentivizing local stakeholders and communities.[26] Metaverse applications cut through the line separating the digital and the real world, and allow, for example, players of video games to have real-world impact.[27] These use cases will generate further carbon credit demand and potentially channel substantial funding towards projects developers and climate change mitigation measures.

Challenges and Opportunities

The VCM has often been referred to as the 'wild west' because of the lack of standardization and specific regulation. Double-counting, non-additionality of projects, and even outright fraud have negatively affected the VCM in the past, so it's understandable that registries are concerned about blockchain-carbon integration. Many believe the integrity of the VCM is on the line. Just as participants in the VCM believe such mechanisms are worthwhile, despite such criticisms and shortcomings, so, too, do those seeking to implement blockchain solutions in this market. A key to successful evolution into blockchain-based carbon market solutions lies with meaningful understanding of the opportunities and limitations of what is essentially an information technology.

Double counting and fake credits

Concerns around fraud and double-counting are fundamental problems that blockchain technology seeks to solve. Through the use of a distributed ledger that all network participants agree on and can read and write to, blockchains ensure that no network participant—even if completely unknown—can spend more than they have or spend what they have more than once. The 'chaining' of public information back to inception on a blockchain makes committing fraud in the state of the assets on the chain incredibly difficult and expensive, because coded rules set boundaries on permitted actions by participants, and all network participants can observe all actions, including nefarious actions, of other participants. These properties can be beneficial for the VCM.

Let us assume there is an off-chain credit (VCU) and a tokenized version of it (tVCU). How can we be sure that the tVCU corresponds to a 'real' VCU and is not created out of thin air? Current market solutions

[24] See Celo Reserve website, 2022, https://celoreserve.org/.
[25] See Climate Collective website, 2022, https://climatecollective.org/about.
[26] See, for example, Regen Network (https://www.regen.network/)
[27] See, for example, Wildchain (https://wildchain.io/), which offers a gamified way to support real-world conservation efforts.

include (1) retiring the VCU when issuing tVCU and having a two-way link between the retired VCU and the issued tVCU or (2) keeping the VCU in a custodial setup and synchronizing the states of the tVCU and the VCU through constant monitoring.[28] Future solutions might follow a different approach altogether.

Once the credits are tokenized, anyone can see the addresses that hold them and whether a particular credit has been retired or not. Protocols typically have a burning mechanism that permanently and irreversibly removes a retired token credit from circulation, making it impossible to resell retired credits.

The amount of credit tokens is tamper-proof and fully in the control of the token issuer. Technically speaking, it requires control over a private cryptographic key, which allows signing transactions on the blockchain. The issuance of new credits is then tied to a cryptographic proof of the right, making it statistically impossible for a third party to create new tokens under the same identifier. Similarly, it is easy to detect fake tokens, as these would link to a different token identifier.

These are pragmatic solutions bridging off-chain credits because VCUs are not issued directly on-chain. If established registries were to use public blockchains for the tracking and transferring of credits, the 'parallel accounting' of on-chain and off-chain credits becomes obsolete; they would be one and the same thing.

The same applies for broader concerns of double counting. There may be concerns that the tVCU world and the VCU world are not synchronized, resulting in a situation where credits are brought on-chain even though they were already retired off-chain, and vice versa. In today's 'parallel accounting' setup, bridging services came up with workarounds that prevent this from happening. With blockchain-native VCUs, the bridging question becomes obsolete.

Standards and interoperability

Verra, Gold Standard and other established offset registries have been developing and refining their standards for years in the absence of binding legislation. It is understandable there may be concerns that credibility is impacted when carbon credits of different standards are traded in a common marketplace.

For example, one could imagine index tokens that represent an average credit across registries. This might undermine the quality from the perspective of an individual registry (e.g., if registry A is considered to be of higher quality than registry B) because the index token would only represent the 'average' credit. But on the other hand, having access to a common market provides for a market-based evaluation of different standards and credit types (e.g., if credits of registry A systematically trade at discount compared to comparable credits of registry B). This is useful price information that would provide for feedback mechanisms to stakeholders along the credit supply chain. This price information is currently largely unavailable.

The concept of standardization of carbon offsets across registries does have a precedent, specifically in the CORSIA market, the international aviation offsetting program. As a quasi regulatory program, airlines are likely to be most concerned around access to eligible offsets, based on rules set by CORSIA. From their perspective, any eligible credit is more or less the same. Today, indexes are being developed where

[28] See the 'bridging services' in the previous section.

CORSIA-eligible credits are being bought and sold with somewhat more transparency. While there are plenty of credits that project developers feel are more valuable and, in fact, sell at a higher price, it could be said that CORSIA-traded offsets represent the 'average'.

Anonymity and traceability

Registries expressed concerns regarding the anonymity of blockchain projects.[29] Transactions on a blockchain are associated with an alphanumeric 'public address' (e.g., 0x872…). This means that while transfers between public addresses and the resulting balances can be easily tracked and verified, the address holders typically remain anonymous unless their identity is explicitly disclosed. This is in contrast to traditional financial transactions, including registries, that rely on a prescriptive, check-the-box KYC process prior to any engagement.

It is important, however, to distinguish between the primary and the secondary market. For example, the issuance of credits might involve a KYC process even in a blockchain-based solution (e.g., to allow a trusted 'bridging service' to transfer credits on-chain). Once on-chain, credit transfers would no longer necessarily involve KYC. From a registry perspective, this is analogous to a situation in which an airline purchases credits from a registry and 'sells' those credits as travel emission offsets to its customers. In this arrangement, the registry does not know which customer emissions are offset with which credits. The public traceability function of blockchains, in fact, offers unprecedented transparency into the transfers and balances of secondary market participants for registries. Anyone can inspect the blockchain at any time.

There may be concerns that a tokenized carbon credit introduces problems of 'double claiming' of credits. For example, a situation in which person A purchases a tVCU, claims an offset, sells the tVCU to person B, person B retires tVCU and claims offset.

While the same can happen with traditional registries, such 'double claims' are arguably easier to dispel with a blockchain-based solution. As the tVCU is on a public ledger, everyone can quickly and cheaply verify at any point in time with blockchain analysis whether a tVCU is still in circulation or whether it entered into a retired state. Person B can therefore point to a retirement transaction on the blockchain, whereas person A cannot.

Another commonly expressed concern is if a token could be used to finance or otherwise be involved in money laundering schemes or even terrorism. While a link between carbon credits and illegal activities seems far-fetched, such concerns should not be dismissed. But it should be noted, according to leading blockchain forensics firm Chainalysis, '*with the growth of legitimate cryptocurrency usage far outpacing the growth of criminal usage, illicit activity's share of cryptocurrency transaction volume has never been lower.*'[30] The application of standard KYC procedures is common practice today among reputable digital asset exchanges, and low-cost blockchain forensics allow for automated and pattern analysis of all transaction activity on public blockchains. Indeed, all asset classes are at risk of illicit use, but blockchain

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[29] Cointelegraph, 2022, *KlimaDAO increases carbon offset stash by 50% in two months*, https://cointelegraph.com/news/klimadao-increases-carbon-offset-stash-by-50-in-two-months.
[30] Chainalysis, 2022, https://blog.chainalysis.com/reports/2022-crypto-crime-report-introduction/.

analytics offer superior and more readily accessible insights for all network participants, including law enforcement.

Legal status

The legal status of digital assets has been another area of evolving debate and lack of consensus. There is often concern around the characterization of digital assets and the triggering of regulation, such as securities registration.

While each digital asset and 'bundle of rights' can be unique, taxonomies are emerging among regulators and function is central to any analysis. If a token offers only the functionality of representing an off-chain VCU, it is likely to be viewed as akin to a VCU. More elaborate arrangements are now possible with the programmable nature of digital assets and automated smart contracts. This is especially true in combination with other innovations impacting the carbon credit 'supply chain', such as artificial intelligence, internet-enabled sensors, and decentralized autonomous organizations (DAOs). For instance, DAOs have potential to involve adjacent and impacted communities in the development of programs as well as economic benefits from primary and secondary market transactions for carbon credits developed in their locality.

Regulatory structures and legal regimes are yet to include or codify many of these novel interactions, but function-over-form analysis can distill the diverse economic activities and distinct rights of the variety of tokens into understandable and manageable assets.

Conclusions

Open blockchain platforms present real opportunities for the VCM in terms of bringing in new buyers and, in turn, new project developers, spurring much-needed immediate action on climate change. The following recommendations are presented to offer suggestions for approaches to tokenizing carbon credits by established registries and other market actors:

- **Assess the first-movers**: The market is moving and first innovators have jumped in. Neutral outside observers should conduct a thorough assessment of how they are working. Outside reviews of current blockchain-market activities, perhaps commissioned by established registries or IETA, should offer dispassionate and comprehensive 'life cycle assessment' of current market operations.
- **Education**: VCUs and blockchains are at best abstract concepts for the vast majority of the world. Players in this space can educate carbon market stakeholders about the security of the blockchain and how to inspect it to see who owns a particular credit and whether that credit has already been retired or not. This means active participation in industry conferences and a willingness to address the earnest concerns of stakeholders, including those who are skeptical of carbon offsets in the first place. The potential for open blockchain platforms to bring new finance and thus new GHG-reduction projects that would not have been financed otherwise—and thus have high additionality—is worth the effort.

- **Commonly-agreed upon audit functions**: As noted earlier, observers can see at any point which address holds which credits and whether a particular credit has already been retired or not. There is concern that a buyer can make GHG-reduction claims even if they sold the token instead of ‘burning’ or retiring it. Platforms could agree—perhaps with the registries, IETA and ICROA (International Carbon Reduction and Offset Alliance)—on specific actions to ensure integrity in the sale of digital carbon offset tokens. For example, platforms could agree in cooperation with blockchain analytics providers to ‘audit’ a random sample of token sellers to ensure that if they sell those tokens, they are making no claims to the GHG attributes. Specific actions could include review of the token sellers’ websites or even randomly asking people to sign voluntary attestations. This is recommended more for larger parties purchasing large volumes of tokens, as opposed to individuals who may buy a few tokens to offset their personal carbon footprint.
- **Token Guidelines/Industry Standard**: ICROA, which accredits individual offset developers, would be in a strong position given its role in the market to establish such standards and/or offer ICROA certification to individual blockchain/carbon offsetting entities. At a minimum, updates can be made to the ICROA Code of Best Practice to address potential concerns and provide useful guidance to token developers working on climate action.