WORLD ECONOMIC FORUM

Blockchain for Scaling Climate Action

WHITE PAPER

APRIL 2023

Images: Getty Images

Contents

Preface

Digital transformation across the environment and climate sector is an urgent opportunity for meaningful action. Other sectors – from retail to finance to manufacturing – have proven the efficiency and productivity benefits of connectivity, automation and data analytics, but the climate sector – where the Intergovernmental Panel on Climate Change (IPCC) has recently underscored the necessity of swift action – is still largely analogue and relies on limited (and outdated) data. To not fully explore and adopt available digital transformation and innovation is the decision to hinder necessary progress on climate action. Conventional methods cannot be relied on to tackle perhaps the biggest-ever threat to humanity. Global climate infrastructure, tools and coordination technologies are needed to keep pace with the changing planetary ecosystem, transcend borders and span social, economic, cultural and governmental domains. This is where blockchain can help.

Blockchain is one of several emerging technologies being explored to address urgent environmental issues such as biodiversity loss, disaster displacement and energy grid deficiencies, as well as resource allocation and coordination – all critical parts of this complex, intersectional, intergenerational and multicultural climate challenge. The defining qualities of blockchains – decentralized, open and global – make them powerful tools that can provide breadth and depth to current climate mitigation and adaptation efforts. Yet, as is the case with any technology, there must be consideration of the unintended consequences, technological maturity and implementation approaches that may impact the people, communities and natural ecosystems already facing climate inaction.

Through ethnographic research, evidence-based climate innovation case studies, and considerations including climate change's historical, political, economic and cultural contexts, this paper investigates how blockchain is incentivizing and can continue to incentivize a planet-positive economy focused on financing regeneration and climate action at scale.

Blockchain can democratize ownership and reallocate resources to shift power dynamics to the people most knowledgeable of, and most vulnerable to, the effects of climate change. Blockchain could also improve the transparency and integrity of existing decarbonization mechanisms like carbon markets. When paired with digital tools for measurement, reporting and verification (MRV) – such as remote sensors, drone imagery and artificial intelligence – digital environmental assets and carbon accounting systems can provide real-time visibility into the effectiveness of emissions reduction and sequestration efforts. As such, these technologies can serve as powerful tools that help communicate and coordinate globally to distribute resources for a world that is flourishing with life.

Blockchain adoption and implementation across decarbonization sectors will require thoughtful coordination, meaningful action across layers of society and industry, education and balanced regulation. Entrepreneurs and investors will be betting on this space not existing in a vacuum. It is hoped that this paper catalyses the important conversations needed to accelerate these emerging technologies to address climate change.

> **When you zoom out and look at all the new technologies coming online — AI, machine learning, remote sensors, blockchain, the list goes on — there's just an incredible potential for unlocking new capital flows into verifiable climate action at scale.**
>
> Anna Lerner, Chief Executive Officer, Climate Collective

Executive summary

The overall objectives of this paper are to 1) curate an evidence-based, balanced and research-driven narrative on the relationship between blockchain and climate action, 2) document examples and use cases of blockchain applications, and 3) offer recommendations to deepen connection and collaboration across current and emerging climate solutions and stakeholders.

Chapter 1 of this paper explores the critical facets that substantiate this generation's climate challenge and what needs to take place to meet the Paris Agreement climate targets. This chapter creates a bridge to how blockchain technologies can help the world meet these targets and create a better future for generations to come.

Chapter 2 contextualizes the value digital technologies bring to decarbonization and climate action. Challenges that stymie progress towards meeting climate targets, such as resource and capital allocation and coordination, are being reimagined through decentralized systems thinking. Blockchain provides an enabling infrastructure with transparency, verification, accountability and democratization as its core pillars.

Chapter 3 provides the foundation for blockchain-enabled climate solutions within the wider context of Web3 and a specific focus on regenerative finance (ReFi). ReFi has emerged as a technological ecosystem that uses blockchain's unique features and other cutting-edge technologies to reimagine extractive economic systems and incentivize regenerative practices. This section provides critical insight into how this diverse industry understands its mandate, objectives and mission as it relates to the broader climate aspirations of the global community.

Chapter 4 delves deeper into key insights from the research. This is divided into two sections: industry trends and industry challenges. Under industry trends, five main themes were consistent through interviews:

Industry experts identified five trends:

1. Tapping into Web3 incentives to strengthen existing climate initiatives
2. More ambitious net-zero commitments
3. Digital MRV solutions emerging as a unifying market force
4. Growing recognition of the benefits of data ownership and interoperability
5. Collaborative culture and the role of community

Industry experts shared five core challenges:

1. Implementation at scale will require unprecedented speed and coordination
2. Reputational challenges facing the industry
3. Overcoming complexity and education gaps
4. Maintaining a focus on real-world impact
5. Lack of regulatory clarity

Chapter 5 provides recommended next steps towards responsible climate innovation and action for three core groups: 1) policy-makers and lawmakers, 2) other climate sector stakeholders, and 3) climate blockchain organizations. There is consensus on the need for constructive regulation and productive dialogue between the blockchain industry, policy-makers and traditional businesses.

This white paper concludes with a look into the future; how on- and off-chain solutions can coincide to drive positive climate impact forward.

Introduction

Using a mixed methodology approach, this report provides context on the convergence of blockchain and climate innovation.

Scope of work

The intersection of blockchain and climate innovation is rapidly evolving, with the potential to scale climate action globally and support progress towards global decarbonization. In this period of rapid evolution, there is a growing need to better understand the opportunities and limits of blockchain and narrow the gap between understanding and the speed of innovation. This paper aims to close this gap by helping to bridge traditional climate mitigation strategies with blockchain-enabled innovation, enabling the navigation of this expanding sector.

This paper offers context, examples and explanations of how blockchain is deployed in relation to climate action and finance.

Additionally, this paper aims to serve as a useful primer to those unfamiliar with regenerative finance (ReFi) as part of the broader blockchain and climate sector. This paper has been designed to guide companies and organizations looking to incorporate blockchain technologies into their decarbonization or net-zero commitments.

Methodology used

This white paper employs a mixed method approach to analyse the impact journey of blockchain-based climate projects, including ethnographic interviews and survey data. Ethnography is a qualitative research method to collect data to help understand the experiences of others. This approach can surface relationships and interpretations that otherwise may be unnoticed, insights that may be crucial when studying an emerging ecosystem. As part of this ethnographic approach, the team of researchers followed a semi-structured interview methodology and developed an interview protocol that was divided into the following subcategories:

1. Background on occupation and demographics
2. Organization-specific history, structure, governance and funding models
3. Monitoring, reporting and verification of real-world environmental impact
4. Equity and decision-making
5. Definitions of Web3 and climate/ReFi
6. Industry challenges

This research also included feedback from subject matter experts within the industry. The interviews included Web3 start-ups, non-profit organizations, established carbon registries and think tanks. The demographic of interviewees ranged in age and span across four continents. Interviewees had experience in climate science, economics, politics, business and technology industries (see the list of interviewees in the “Acknowledgements”). Each interview was recorded and transcribed and then analysed and synthesized. Over four months, 23 hour-long ethnographic interviews were conducted with diverse climate action projects across a range of thematic areas (see “Industry trends” section for more information on themes) and produced over 320 fieldnotes.

The research team also collected over 60 online surveys capturing a snapshot of leading blockchain projects to aggregate industry trends and insights on blockchain and its climate impact. The organizations surveyed varied in size, development stage, geographic focus and approach to blockchain tooling. Combining in-depth ethnographic interviews and short-form surveys allowed for a comprehensive analysis and holistic approach to the emerging blockchain and climate sector.

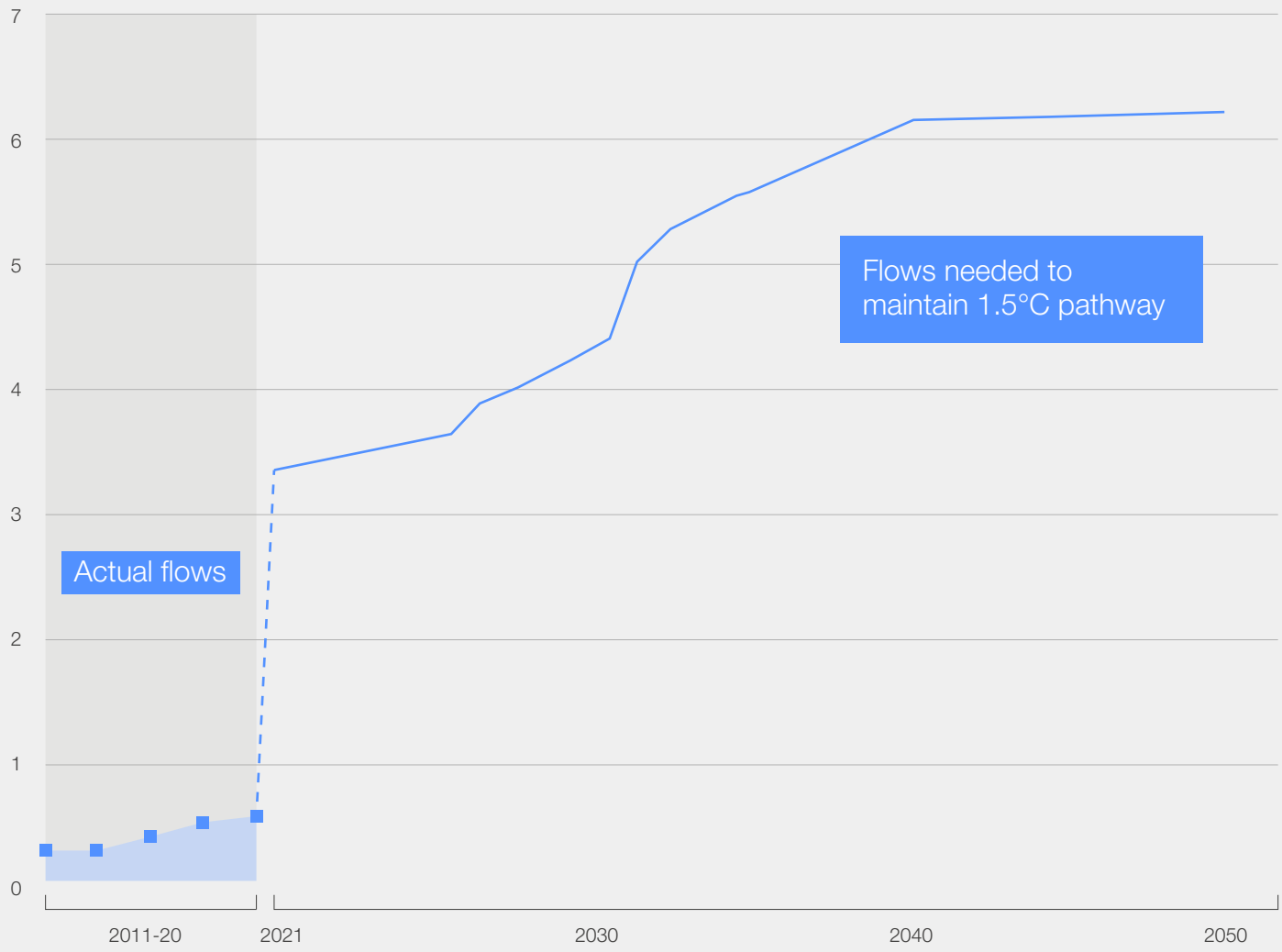
1 The challenge

Efforts to reach climate targets face coordination and incentive problems.

To succeed in global efforts to limit global temperature rise beyond 1.5°C, the Intergovernmental Panel on Climate Change (IPCC) estimates that global greenhouse gas emissions must be cut by 50% by 2030 and reach net zero by 2050.[1] The global community has spent almost three decades trying to align responsibilities and processes to meet these goals, centred around the total permitted amount of greenhouse gas (GHG) in the atmosphere to avoid catastrophic climate change and a reporting system for GHG inventories. These efforts seek to resolve the conflict between the self-interest of the individual user in relation to the common good and the collective interest, a delicate balance of building trust and climate positive behaviour.

Meeting these ambitious targets will also require global capital flow into verifiable, high-quality decarbonization projects at unprecedented speed and scale. Simply put, there is a need to direct substantial investments into effective real-world climate mitigation projects, and it needs to be done quickly.

FIGURE 1 **Trillions more dollars of climate finance investment is needed to maintain 1.5°C pathway[2]**



IMF

Source: Buchner, Barbara, et al., *Global Landscape of Climate Finance 2021*, Climate Policy Initiative, 2021.

If a sustainable, net-zero emission and resilient world is to be achieved this decade, climate finance must reach $4.35 trillion annually by 2030.

The world is not on track. Challenges include both private and public opacity related to climate goals, inadequacies related to accountability mechanisms and interoperability (as well as transparency) of tracking systems. Furthermore, climate finance isn't growing quickly enough to meet climate goals. According to the Climate Policy Initiative,[3] $632 billion has been invested in climate finance (public and private). Although this represents an increase over previous decades, if a sustainable, net-zero emission and resilient world is to be achieved this decade, climate finance must reach $4.35 trillion annually by 2030. The level of coordination and incentives required to transfer money from enterprises in developed countries to land stewards in emerging economies in an effective, verifiable way has been underestimated. What is the strategic, practical and maximum multistakeholder benefit approach to moving forward?

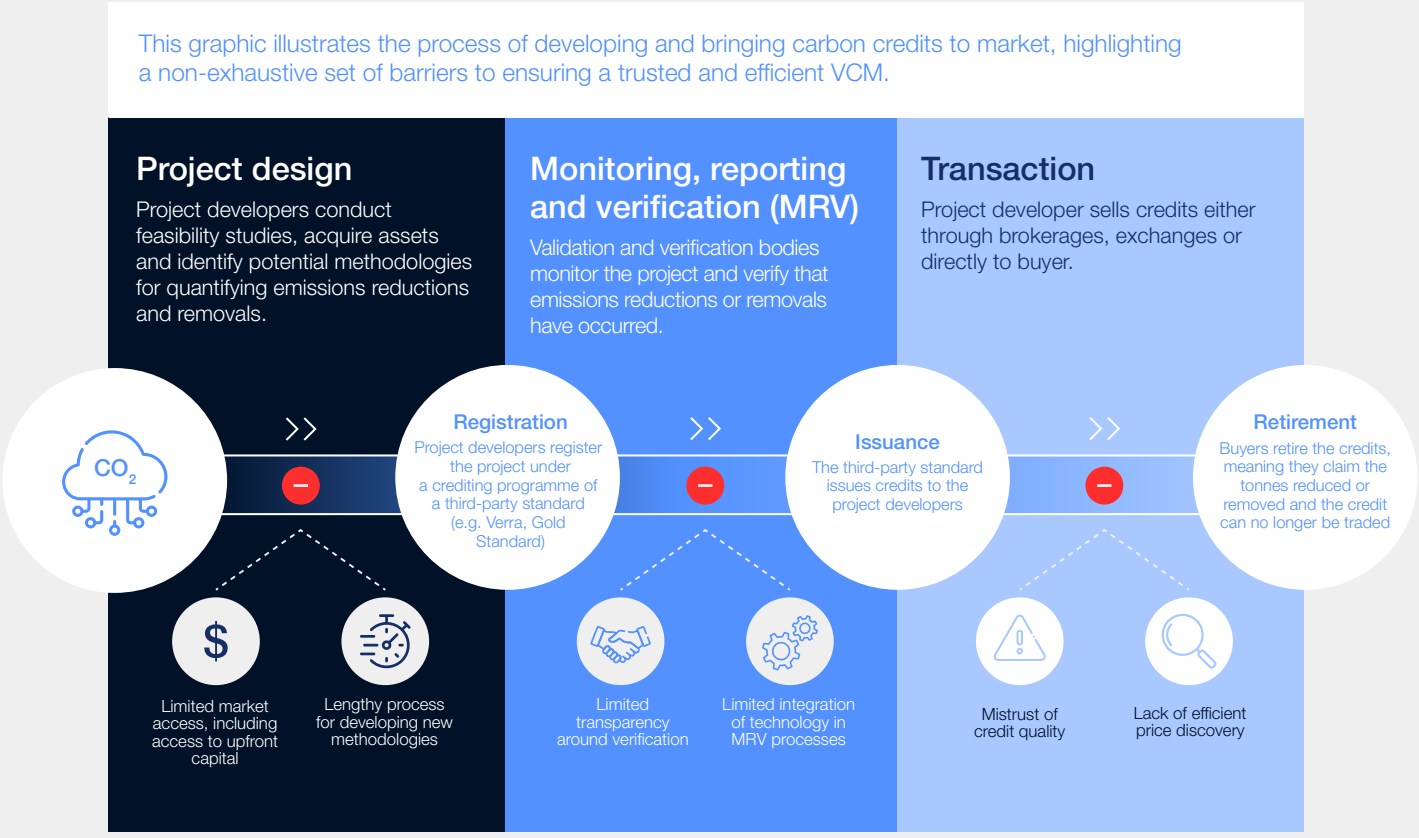
Encouraging progress has materialized within the business community regarding setting voluntary targets to reach net zero. Similarly, nation-states have demonstrated progress in collaborating more effectively to achieve ambitious nationally determined contributions (NDCs). Each country's contribution aims to reduce national emissions and adapt to the impacts of climate change.

The voluntary carbon market (VCM) is an existing market mechanism that the global community can use to channel enterprise capital into land conservation and environmental stewardship. According to a recent McKinsey report, "Voluntary carbon credits direct private financing to climate projects that would not otherwise get off the ground, and they support investment into innovation required to lower the cost of emerging climate technologies".[4]

Yet today's carbon markets are challenged by fragmentation, complexity and have struggled with public trust over the years[5] – the most critical of its challenges may be its inability to credibly demonstrate and verify the impact of carbon offsetting measures.[6] The Rocky Mountain Institute (RMI) visualized[7] the complex value chain and can be considered a primer for anyone trying to better understand this market.

FIGURE 2 **Life of a carbon credit**

This graphic illustrates the process of developing and bringing carbon credits to market, highlighting a non-exhaustive set of barriers to ensuring a trusted and efficient VCM.



Source: "Carbon Markets Initiative", *RMI*, n.d.

To solve this challenge, entrepreneurs around the world are making use of the latest advances in digital technologies, including high-speed connectivity, advanced analytics and other emerging technologies like blockchain, satellite imagery and artificial intelligence (AI) to build more efficient climate markets, speed up decarbonization and build out interoperable accountability systems – all to rapidly enable verifiable climate action at scale.

2 The value that digital technologies bring to decarbonization and climate action

Blockchain can provide the necessary infrastructure to combat climate change at speed and scale.

Digital technologies, including blockchain, can provide an enabling infrastructure layer needed to manage (and account for) rapid increases in the speed and scale of global climate action, with integrity and efficiency programmed in from the beginning. Based on interviews and research, blockchain's value propositions can be broadly categorized into four categories.

1 Blockchains can strengthen trust and ambition in climate negotiations

The climate crisis is the ultimate "tragedy of the commons", where responsibility for managing common property resources like biodiversity and a livable climate is transferred through the Paris Agreement to national actors. From there, the responsibility falls to sub-national and non-state actors, whose self-interests and incentives often conflict with the common good. The United Nations Development Programme (UNDP), responsible for supporting more than 120 countries to strengthen NDCs, has concluded that a lack of integrated data systems and varying measuring methodologies will pose challenges to setting ambitious climate goals and accurately measuring global climate progress.[8] They have called for interoperable and open source climate-focused digital public infrastructure (DPI) to enable transparent measurement, reporting and verification (MRV) and aggregation of NDCs at scale across countries.[9] A recent impact study[10] estimates that a replicable digital NDC monitoring system with interoperability between reporting mechanisms and climate finance platforms across countries could lead to reduced carbon emissions by 2030 (in amounts that are at minimum 3-4% of low and middle-income countries' targets).

Web3 tools like blockchains, decentralized data systems and identifiers, and verifiable credentials provide the underlying data infrastructure and interoperability standards needed to build such systems and coordinate progress against NDCs at a global scale. Due to their decentralized structure and trustless, tamperproof processing features, Web3-enabled climate accounting would align incentives across government stakeholders that may otherwise be unlikely to trust each other. This would provide a path to solve the fundamental accountability and incentive problems endemic to global climate negotiations.

Solving economic incentives is equally important on an individual or corporate level. All levels of society should contribute to decarbonization and raise the ambition of joint efforts.

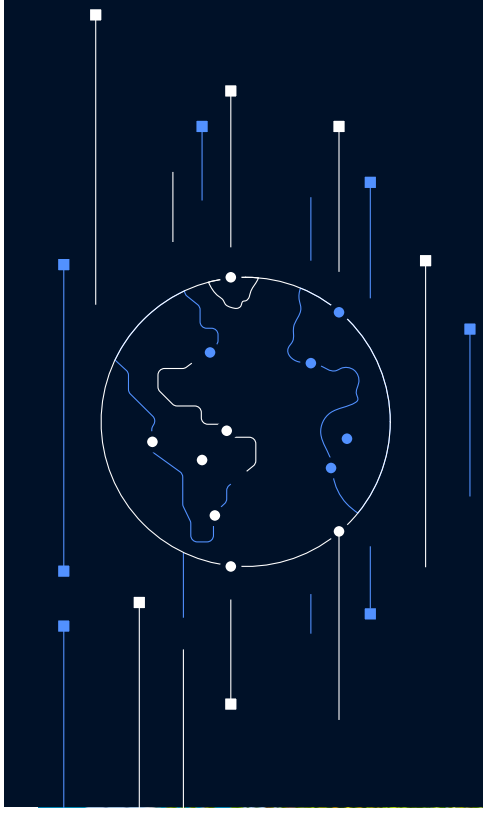
> **We've embedded economic incentives for companies and individuals to nudge them to do things that are good for the planet.**
>
> André Vanyi-Robin, Co-Founder and Chief Executive Officer, Plastiks

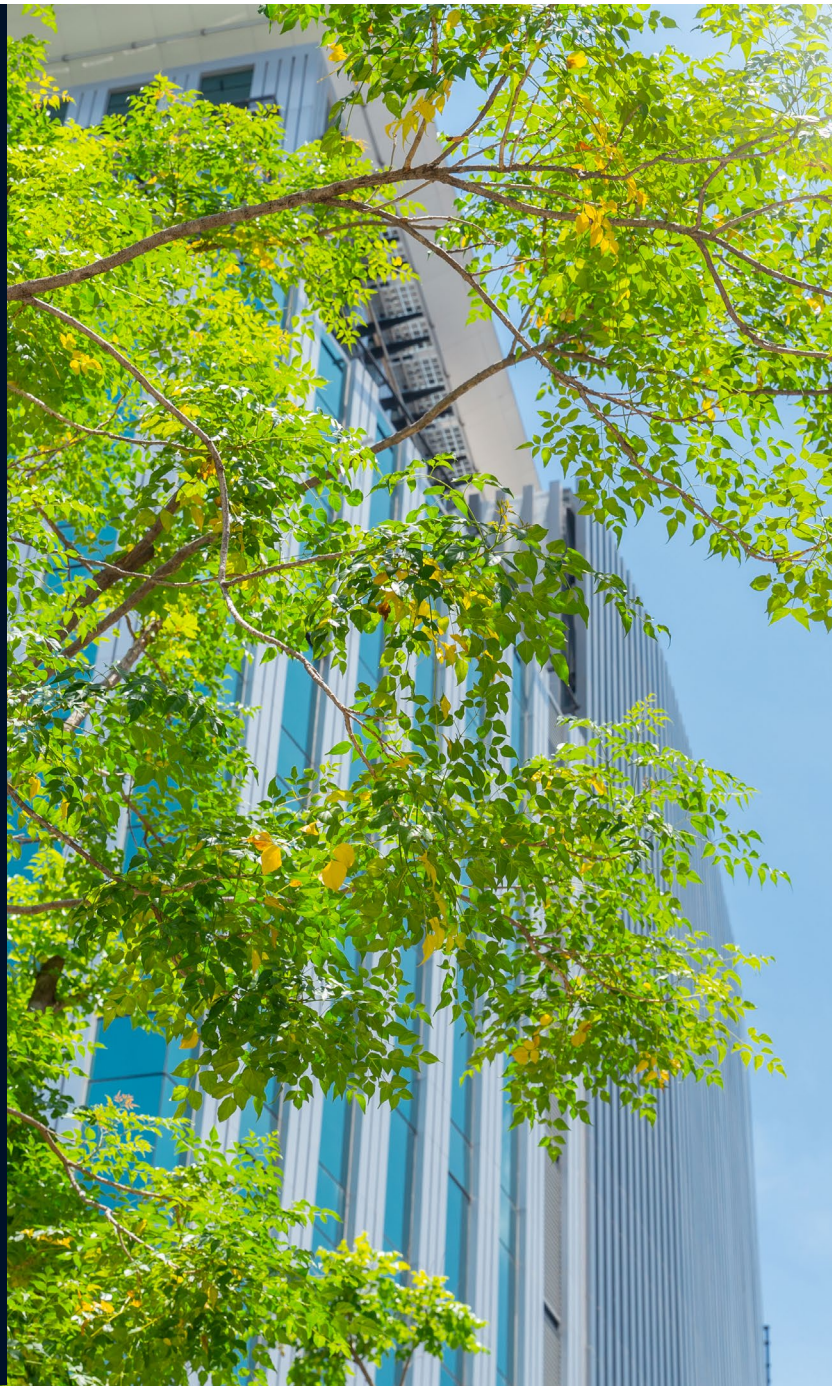
2 Blockchains and digital MRV technologies can improve market transparency and credibility

Digital technology has much to offer to corporations in the effort to counter climate change. The VCM is predicted to grow exponentially: from $2 billion in value in 2021 to $50 billion in 2030.[11] Yet, as the VCM has begun to scale up to meet growing corporate demand for carbon offsets to meet net-zero targets, transparency has become a concern. For carbon markets to deliver on their promise, corporate buyers (and the general public) need to have confidence in their quality and integrity: carbon offsets need to transparently demonstrate causal and durable change to GHG concentrations while proving they are free from credibility concerns like double counting or leakage.

Due to their public, accessible and machine-readable format, blockchains can provide a transparent foundation necessary for a trustworthy and scalable VCM. When carbon registries are built on blockchain, market participants can view a transparent digital record of every credit across geographies and standards, allowing global price and supply coordination. When paired with digital tools for MRV – such as smart meters and sensors, drone imagery and data science – digital carbon accounting systems can provide real-time visibility into the actual effectiveness of ongoing carbon sequestration efforts. Such transparency removes the risk for corporate buyers who want to ensure their net-zero budgets are going towards measurable, verifiable climate mitigation efforts.

> **What's unique is that you have this immutable log of what's happened, when it happened and why it happened, which makes the process of doing due diligence or auditing much more straightforward, much more simple.**
>
> Miles Austin, Chief Executive Officer, Hyphen





> **[Blockchains provide the] ability through smart contracts to pull revenue from secondary market transactions back to project developers in a way that just doesn't happen in the typical carbon market.**
>
> Hugh Salway, Senior Director, Market Development and Partnerships, Gold Standard

> **A decentralized set of infrastructure can run applications that remove rent seekers and put more money directly in the hands of people.**
>
> Ben West, Grant Programmes Lead, Gitcoin

3 Digital carbon markets can funnel more money to project developers

Digital environmental assets help streamline asset discovery and purchasing. In contrast, digital carbon markets reduce the need for intermediaries who advise, broker, and manually collect and process data in conventional carbon markets. Blockchains can therefore help disintermediate the carbon value chain and reduce transaction costs, ideally with more financing reaching project developers on the ground. These developers are the actual stewards of the underlying environmental assets.

Digital markets can also improve access to financing for project developers. Project owners often use pre-purchase agreements to attract financing for their work, but without clear price signalling in conventional markets, sellers can be forced to offer their credits at a steep discount. If smart contracts can access publicly available pricing data on public ledgers, project owners may have more negotiation leverage. Such price availability can also make buyers more comfortable because smart contracts can auto-execute pre-purchase agreements once credits have been developed, thereby reducing counterparty risk.

4 Digitization democratizes access to climate action

Conventional carbon finance markets are restricted to large institutions because carbon credits are not typically sold in volumes that are less than one tonne of carbon sequestered. However, the recent movement to "tokenize" (i.e. digitize) credits has enabled fractional (i.e. sub-tonne) ownership of credits, allowing individuals and smaller organizations to participate in the market. In addition, fractionalized credits make considerably high-value credits like tech-based carbon dioxide removal (CDR) credits, which can cost hundreds of dollars per tonne, accessible to smaller buyers. Besides expanding access to carbon offsetting to the broader public, blockchain's participatory culture is inspiring a new wave of climate action by younger generations who see the technology as a tool for empowerment. The ecosystem is compared with what Benoît Clément, Director of Financial Innovation at Verra, refers to as "the digital evolution of grassroots activism" that values regeneration over extraction.

3 Beyond technology: blockchain, Web3 and regenerative finance

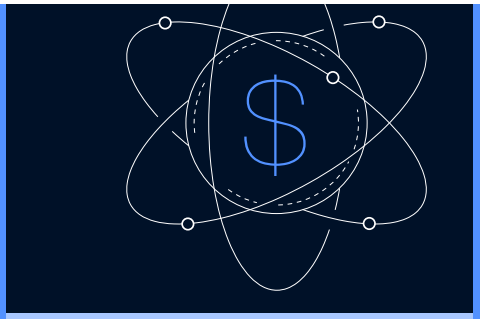
ReFi is harnessing the benefits of blockchain to build systems and services that support an inclusive and regenerative economic system.

Web3 is an evolution of digital infrastructure based on design principles including decentralization, democratized access, direct ownership, open source and interoperable code, verifiability, and incentive design. Based on these new principles, companies are building solutions that integrate blockchains, consensus networks, decentralized data storage systems, privacy technologies, cryptocurrencies, non-fungible tokens (NFTs), decentralized autonomous organizations (DAOs), decentralized finance (DeFi) and ReFi protocols. Web3 systems enable users to have more control over the digital ecosystems they are active in, as well as a financial stake. However, while blockchain is often promoted as a solution to privacy, transparency and financial inclusion, it has created concerns about those same challenges.[12]

ReFi fits within the broader Web3 sector. Viewed as the blockchain industry's value proposition to the global climate mission, it intersects with climate technology, sustainable development, climate finance, economics, regenerative practices, impact investment and climate justice – to name a few. Given the several intersections that ReFi has with other domains, many leaders and creators across the Web3 apparatus view its definition and their purpose within it differently.

What remains foundational across these definitional iterations of ReFi is that it seeks to build financial tools, make use of token economics incentives and create services that embody an inclusive and regenerative, rather than extractive, economic system.

> **... For me, regenerative finance is about redefining what value means and how do we redefine that in a way that is supportive of the world rather than destructive ... What regenerative finance means is how do we bring value that supports a healthy, fair planet into our economy.**
>
> Stefan Renton, Sustainability Lead, Polygon Labs



> **From my perspective, the economy today is extractive, focused solely on GDP growth with little regard for externalities punishing people and the planet. ReFi challenges that by creating a financial structure where the economic activity has a positive impact on the ecosystem.**
>
> Jack Policar, Product Manager, Climate Builder Hub, Toucan Protocol

> **Regenerative finance are instruments and systems that increase the evolutionary capability and capacity of life on Earth.**
>
> Gregory Landua, Co-Founder and Chief Executive Officer, Regen Network

> **ReFi is about stripping away the consumptive or extractive nature of a lot of our capitalist financial instruments, systems, services and reimagining them to be regenerative.**
>
> Lucia Gallardo, Founder and Chief Executive Officer, Emerge

> **ReFi enables programming of incentives that lead to changed behaviour for the better of the planet – and empowers local communities to monetize stewardship of their natural capital and ecological assets – something we know is critical to ecosystem restoration and biodiversity protection.**
>
> CJ Hetherington, Co-Founder, Atlantis World

As with other movements, the ReFi ecosystem has attracted various products, services, solutions, individuals and business models. Table 1 lists the various use cases, technologies, services and business models encountered throughout the research.

TABLE 1 **ReFi ecosystem examples**

Categories within the ReFi ecosystem*	Examples
Building digital carbon market infrastructure	Thallo, Toucan, MOSS.Earth, Regen Network, Allinfra, KlimaDAO
Climate financing and liquidity for VCM	Solid World, Flowcarbon
Blockchain marketplaces	Senken, Atem, Sushiswap, Thallo
Carbon accounting and environmental, social and governance (ESG) data reporting	Allinfra Climate
Open MRV for forestation data	Open Forest Protocol, GainForest
Origination of ecological credits	Regen Network, Carbonbase, Kolektivo, CarbonPath; Rebalance Earth
Regenerative agriculture and smallholder farmer lending	ReSeed, EthicHub, Regen Network
Waste management efficiency and plastic credit marketplace	Sanergy, Plastiks, Zero Waste Foundation
Distributed energy supply, energy independence and microgrids	EnergyWeb, Reneum, Unergy
Gamification of impact and carbon offsetting with education aspects	Atlantis World, Ecosapiens, Avatree, Wildchain, Impact Arcade
Innovation in air quality monitoring and overall public health	PlanetWatch
Real-time verifiable climate data aggregation	Hyphen, dClimate
Decentralization and decarbonization of data storage	Filecoin Green
Funding public goods and impact projects	Gitcoin, Climate Collective, Mercy Corps Ventures, Ripple Sustainability Fund
Generating new pathways for impact	Emerge, GoodDollar, Ethereum Climate Platform
Community building and education	Climate Collective, ReFi DAO
Conservation and biodiversity	Preservaland, Credit Nature
Carbon neutral blockchains	Polygon, Algorand, XRP Ledger, Celo, Ethereum, Hedera, Filecoin
Open source and interoperable climate-focused digital public infrastructure	Protocol Labs, Hedera Guardian, Astral Protocol, CAD Trust, OpenEarth

** Please note this list is not exhaustive. This highlights organizations and projects that were interviewed, participated in the survey and part of the research process for this paper.*

4 Industry trends and challenges

An explanation of trends and challenges within the blockchain and climate action ecosystem.

Industry trends:

1 Tapping into Web3 incentives to strengthen existing climate initiatives

Blockchain technology has seen an increase in adoption by global institutions within the last few years. The World Bank, for example, established the Climate Action Data Trust,[13] which uses blockchain technology to coordinate global carbon data and pricing within its broader Climate Warehouse initiative. Leading investment banks are also embracing blockchain adoption, including Goldman Sachs, which recently rolled out its Data Asset Platform, GS DAP, to issue digital bonds on a private blockchain.[14] Leading global corporations like Microsoft have integrated blockchain technology into their supply chain management operations to improve transparency and facilitate more efficient coordination between global business units.[15]

> **IETA supports the vision of the Climate Action Data Trust, to create a single source of truth for carbon markets which allows anyone to see the state of the VCM at any point in time.**
>
> Alasdair Were, Adviser, International Emissions Trading Association

Compared to late 2021/early 2022, when the discussions on blockchain as a technology for climate action began, a notable trend is an uptick in meaningful interaction between traditional climate stakeholders and blockchain-enabled climate groups. This is particularly visible in the carbon credit industry. For example, the International Emissions Trading Association (IETA) set up a digital markets task force[16] to explore the role of digital and decentralized technologies in emissions trading. Gold Standard launched a digital MRV pilot in early 2022 after conducting stakeholder consultations and working groups[17] to explore options. Verra has conducted similar consultations and is revising its digital strategy.

As corporate and policy-making institutions become familiar with blockchain technology's practical applications and cost and efficiency gains, there is reason to believe that adopting digital climate solutions will happen at the speed and scale needed to meet global decarbonization goals.

2 More ambitious net-zero commitments

According to a 2022 Accenture report, 34% of the world's largest companies have a public net-zero target – up 7% from the previous year – and companies with net-zero targets are cutting emissions faster than those without.[18] With the proliferation of net-zero commitments comes a strong signal of future demand for carbon offsets. As corporate sustainability teams ramp up their efforts to find and fund high-quality decarbonization projects that will offset emissions, they are unable to reduce by improving their business operations. Such an aggressive net-zero agenda from global corporate leaders underscores the need for a rapid scale-up in the supply and efficiency of voluntary carbon markets and for global digital infrastructure that can support this rapid growth.

Some leading corporations are going beyond net-zero commitments. Stripe, Alphabet, Shopify, Meta and McKinsey & Company recently pooled $925 million into Frontier, an advance market commitment to buy permanent CDR credits. These buying groups signal that financing will be ready for suppliers who can generate high-quality CDR solutions.

Within the blockchain industry, several layer-one blockchains have recently ramped up their focus on climate impact and digital carbon markets. Projects like the Ethereum Climate Platform,[19] Hedera's $100 million Sustainable Impact Fund,[20] Ripple's $100 million commitment to global carbon markets[21] and Celo's commitment to operating a carbon-negative blockchain[22] indicate that industry leaders are preparing blockchain technology for an increasingly important role in global decarbonization efforts.

> **Bringing the climate change problem into Web3 allows the climate change sector to benefit from this incredible vibrant industry that's been built around blockchains.**
>
> Max Song, Chief Executive Officer, Carbonbase

3 Digital MRV solutions emerging as a unifying market force

Supply and demand-side stakeholders are uniting behind the value of digital MRV solutions to verify the state of real-world natural assets and any subsequent digital environmental assets they represent (i.e. tokenized carbon credits). As policy-makers have begun to recognize the insurmountable operational challenges, costs and time lags associated with manual climate impact measurement and verification at a global scale, they have increasingly turned to digital MRV technologies to close the gap.

Creative solutions for enhanced verification have continued to surface over the past year, including impact certificates (i.e. Hypercerts[23]), renewable energy certificates (i.e. Reneum,[24] AllInfra,[25] Zero Labs[26]), and third-party verification and green guidance documentation (i.e. Filecoin Green[27]). Platforms such as Hedera's Guardian[28] provide tailored solutions to track the life cycle of any type of digital environmental asset, spanning MRV data, market transactions and retirement claims for carbon credits – where multi-step review processes are embedded in the token metadata with automated audits.

At COP27, the leading global carbon standard Verra launched a digital measurement, reporting and verification (dMRV) pilot programme with Pachama.[29] Google and SIP hosted the Accelerating Digital Environmental Assets Summit in Mountain View in October 2022,[30] focused on driving the deployment of dMRV tech for a digitally native VCM. Open Earth Foundation launched its OpenClimate platform to support global stocktaking under the Paris Agreement and enhance international coordination efforts.

> **dMRV could provide an opportunity to continuously improve methodologies, instead of the current situation where it might be a year, five years, ten years until you detect problems with mostly anecdotal evidence at that point. Here, we can build in continuous enhancements that are driven by real-time data.**
>
> Benoît Clément, Director, Financial Innovation, Verra

With the help of novel incentives and ownership models, blockchain can enable more participatory data collection. Several groups are working on solutions to automate carbon credits' certification and verification processes by combining blockchain tools, AI, machine learning, remote sensing, satellite imagery, oracles (bringing real-world data on blockchain), and internet of things (IoT) networks with human input data. The latter is often termed "citizen science" (Claudio Parrinello, Chief Executive Officer, PlanetWatch), where "the power of the crowd" (Fred Fournier, Chief Executive Officer, Open Forest Protocol) ensures higher quality, granular and timely data.

4 Growing focus on data ownership and interoperability

Major institutional and regulatory bodies highlight the need for interoperable global data infrastructure. This is particularly relevant for cross-border initiatives such as the UN's Global Early Warning Initiative, which aims to funnel $3.1 billion into targeted investments to reduce disaster risks before hazardous weather events. Many blockchain companies are building pieces of this global data infrastructure – for example, Filecoin's CO2. Storage platform and OneShot's Open Carbon Protocol. Hyphen is building a real-time, validated observation-based climate data platform and a related climate data oracle[31] – complementary to RMI's *Principles for Blockchain-Based Emissions Reporting*.[32] Integrating these digital technology platforms into a broader global data infrastructure strategy indicates an institutional readiness for distributed ledger solutions that will address bottlenecks faced by conventional carbon accreditation and climate risk systems.

5 Collaborative culture and the role of community

Entrepreneurs building at the intersection of blockchain and climate have a strong sense of community, evident in solutions design and governance models. Across the regenerative finance ecosystem, there is wide recognition of local stewards' rights to land and resources – and many solutions are being designed to cement local communities' right to the "carbon benefits generated on the land and empower them with the right to decide the fate of the land that they occupy", according to Hara Wang, Principal of Climate Intelligence at RMI. The sector has built innovative partnerships with custodians of the rainforest (Emerge), assemblies with communities (Moss) and other forms of embedded community consultations, to ensure equity in decision-making.

> **What we are trying to promote is a dialogue between equals, we're moving away from the historical perspective of the colonialist lender giving money to the poor farmer.**
>
> Gabriela Chang, Co-Founder and Chief Sustainability Officer, EthicHub

In an attempt to operationalize this value for local land stewards and equitable decision-making, most ReFi projects incorporate an element of community governance. For example, Gitcoin has a Stewards Council where people with a GTC token vote on resolutions. Regen Network is governed by the community through token staking, which, according to its Co-Founder and Chief Executive Officer, Gregory Landua, aims to "create a community governed core. That also includes non-Web3 actors, like Indigenous people and farmers, cooperatives and scientists". Overall, the ecosystem is seen as an inclusive and collaborative community with a global team of contributors thanks to the open-source nature of blockchain tools.

Industry challenges:

1 Implementation at scale will require unprecedented speed and coordination

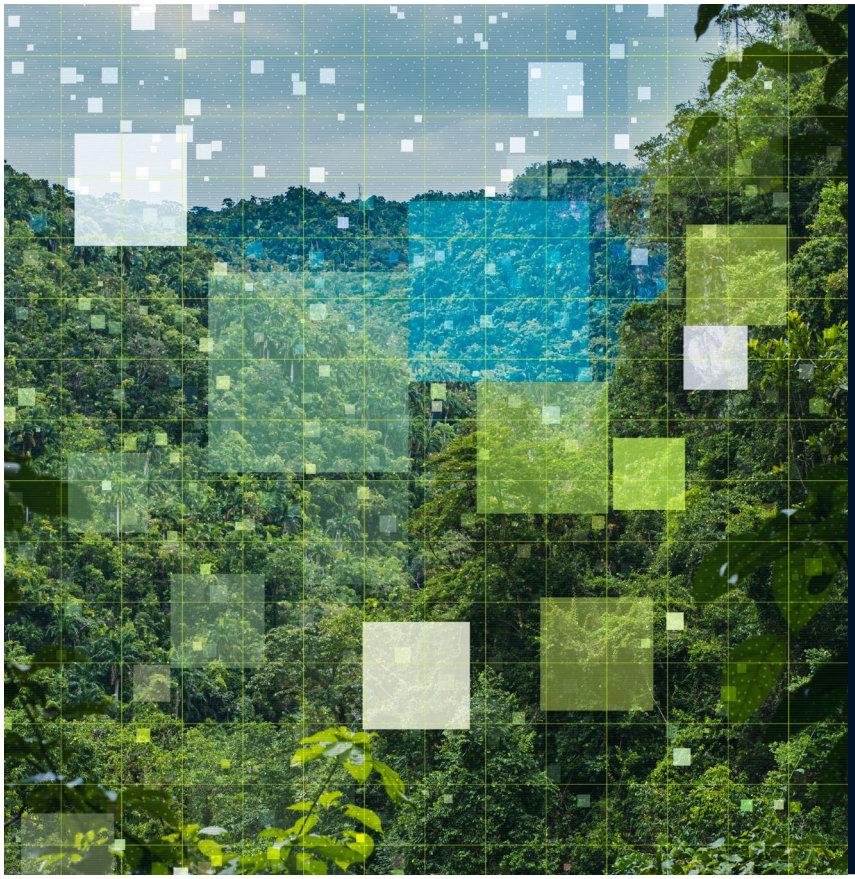
As one part of the larger global initiative to address climate change, carbon markets need to scale rapidly over the next decade to keep pace with global decarbonization goals. However, achieving such speed and scale will require unprecedented coordination across a highly diverse group of industry stakeholders – from regulatory agencies to certification standards, corporate sustainability teams to technology start-ups, and international policy-makers to local farmers and land stewards.

The advantages of digital carbon markets over conventional markets are clear, and a digital transformation is likely necessary for carbon markets to meet the moment. Unless the industry "threads the needle" and implements these significant changes quickly, achieving implementation at the speed and scale necessary to meet climate goals will be difficult.

2 Reputational challenges facing the industry

As carbon markets have grown, they have become increasingly scrutinized due to perceived credibility issues. Among the general public, and even within climate advocacy groups, carbon offsets can be viewed with scepticism due to their potential to be used for corporate greenwashing. Market transparency and climate impact verification improvements are necessary to support enough public trust for the regenerative finance industry to succeed.

Blockchain technologies face their own reputational issues as well. Historically, due to massive fluctuations in cryptocurrency markets and high-profile scandals, "crypto" has been associated with bad actors and scams. This negative association hurts the credibility of blockchain-based climate technology applications and may result in slower adoption by key stakeholders due to perceived reputational risk. This public perception problem slows the impact and effectiveness of blockchain-enabled climate solutions and hinders their ability to meet the moment.



> **If we don't have a foundation of scientific-quality climate data that's timely, tamper proof, verified, accessible and easy to work with, the chances are higher that we recreate a 2008 situation in ReFi or in the larger greening of the financial system.**
>
> Miles Austin, Chief Executive Officer, Hyphen

3 Overcoming complexity and education gaps

The fast-paced and technologically complex nature of the blockchain climate ecosystem presents a unique challenge around educating the climate community (and the broader public) on the value the technology brings to climate action. The sector needs to expand initiatives to build public awareness and trust. Alasdair Were, Adviser at IETA, comments, "I think the Web3 community could do a better job of coordinating and explaining the technologies they've developed to the major carbon buyers of the world". The space needs spokespeople to communicate and build bridges with members of the broader climate and policy-making community who are not blockchain experts.

Beyond the education gap, the regenerative finance sector is sometimes accused of elitism and operating in an echo chamber due to some ReFi community members dismissing existing structures as legacy standards. To scale impact, the sector must instead build mutual understanding, recognize the essential role of historical market participants and learn the lessons of an industry that has existed for decades.

4 Maintaining a focus on real-world impact

Due to the digital nature of the blockchain climate ecosystem, the ReFi community has been criticized for being focused on digital engagement over real-world climate impact. Industry advocates have expressed concern that it can be difficult to discern between messaging and impact. Gregory Landua, Co-Founder and Chief Executive Officer of Regen Network, stated, "Sometimes there's a lot more emotion than there is movement". Of course, the industry's success depends entirely on its ability to accelerate real, verifiable climate change mitigation efforts. As projects mature, it is important to prioritize emissions reductions and regenerative practices on the ground over flashy technology or clever tokenomics schemes.

The tendency to artificially assign importance to a project due to its marketing rather than its proven impact is another important pitfall for the ecosystem to avoid. Such "hype" cycles sometimes come at the cost of positive action. Lucía Gallardo, Chief Executive Officer and Founder of Emerge, commented, "Very visible or noisy or flashy projects tend to get the most amount of attention and consequently the most amount of participation in the market".

5 Lack of regulatory clarity

Both the blockchain and climate spaces suffer from regulatory uncertainty. Lack of definitive understanding of whether digital environmental assets are considered securities or commodities stalls progress in the sector. Additionally, the role of the U.S. Securities and Exchange Commission's forthcoming recommendations and how they will affect tokenized carbon credits are still unclear. Science Based Targets initiative (SBTi) delaying guidance on what qualifies as a net-zero contribution adds to the challenge.

5 Recommendations

The blockchain industry should learn from the evolution of the climate industry, build more multistakeholder partnerships and focus on scaling responsibly.

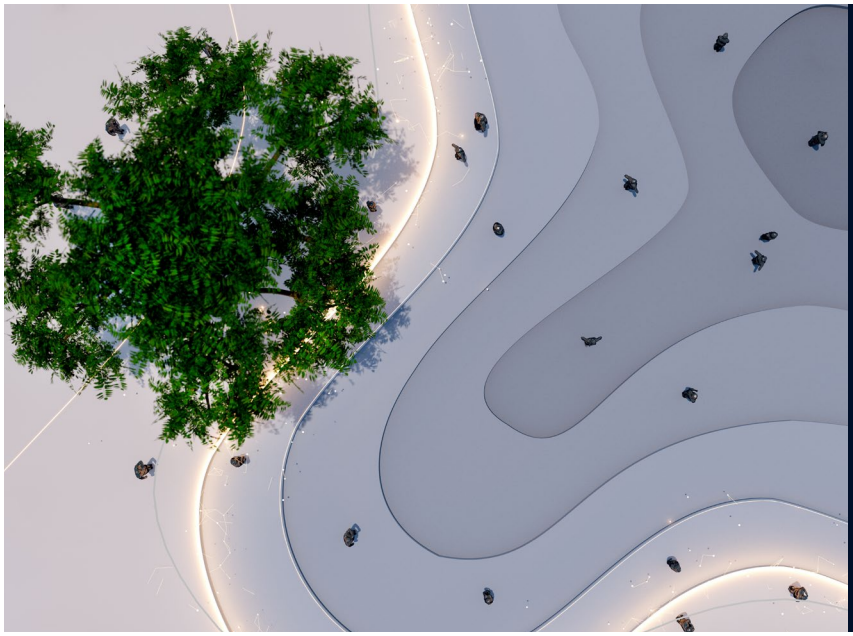
For policy-makers and lawmakers

The speed and scale of digital climate technology's adoption will depend on how policy-makers approach this new industry. International institutions like the World Bank are already using blockchain to connect global carbon registries,[33] but the UN and the Intergovernmental Panel on Climate Change (IPCC) will determine how governments will use such global carbon databases. Similarly, the adoption of downstream digital climate applications (such as dMRV) will depend partly on how regional and local governments design policies and incentives related to their use.

Industry leaders agree on the need for constructive regulation to enable responsive digital climate innovation at scale. Such constructive regulation will depend on whether policy-makers take into account the wide variety of blockchain use cases (e.g. cryptocurrencies vs NFTs vs digital environmental assets vs real world assets) to give space for further innovation in climate-oriented blockchain applications. Industry leaders worry that blunt policy instruments meant to regulate "crypto" as a whole may stifle innovation. Some technical understanding of blockchain mechanisms, incentive structures, tokenomics, as well as the application of blockchain in composable systems that can redefine GDP value with the incorporation of these asset channels[34] will be important for lawmakers to be able to differentiate between diverse technologies. Miles Austin, Chief Executive Officer of Hyphen, stated, "it's important to actually set them aside from each other and not just treat them as the same".

Certain jurisdictions will likely slow innovation, whereas other jurisdictions will make more nuanced, climate-forward policies and attract entrepreneurial activity and climate finance inflows. Some jurisdictions may prevent digital carbon market adoption entirely.

> **It's really important that when lawmakers think about blockchain, they understand the variety of applications of blockchain and not just the use cases that sometimes dominate the headlines. This goes beyond cryptocurrencies, and encompasses what you can build on blockchain.**
>
> Dana Gibber, Co-Founder and Chief Executive Officer, Flowcarbon



> **It's very possible that we have jurisdictions that either prohibit certain project types accessing the voluntary carbon market or start to tax them to an extent where the project types just don't become viable.**
>
> Hugh Salway, Senior Director, Market Development and Partnerships, Gold Standard

To deepen understanding and trust, the industry would benefit from building relationships with regulators through targeted educational campaigns and collaboration between climate-focused blockchain communities, lawmakers and policy-makers.

For other climate sector stakeholders

Many business leaders are likely unaware that digital blockchain technologies are being developed to help them meet their sustainability goals and net-zero commitments. Corporate sustainability teams may benefit from increasing their understanding of this new product ecosystem to determine whether particular applications may fit into their ESG and decarbonization strategies. In this early phase, corporate investment has the potential to significantly accelerate innovation and overall industry growth. The industry would do well to educate corporate clients and find ways to strike new partnerships with market-making potential.

Non-profits, non-governmental organizations, think tanks and research institutions have important roles to play, both in terms of capital allocation and contextualizing digital technologies for regulators. Institutional research into the space would go a long way in helping make sense of this new and complicated industry and determining which technologies policy-makers should focus on. Corporate-oriented researchers and impact portfolio curators can help their clients by developing expertise in identifying high-integrity digital impact credits across a range of new dimensions (natural capital integration, biodiversity, social, health, etc.) to help businesses better compensate for negative impact by retiring diversified baskets of impact certificates.

> **[It's important to] teach founders how to appeal to institutional investment in organizations and then teach organizations how to understand and navigate a space that's very difficult to understand, because it's very new, very experimental, very fast-paced and very complex.**
>
> Lucia Gallardo, Chief Executive Officer and Founder, Emerge

For climate blockchain organizations

As the industry continues to grow, educational campaigns will deepen institutional ties. The industry's fate depends on whether the ecosystem engages with institutions, policy-makers and lawmakers to build partnerships and learn important historical lessons.

Likewise, Web3 companies should continue to embrace and promote the democratic benefits of blockchain technology by developing more public, open-source products with community governance features built-in.

Climate blockchain organizations need to stay laser-focused on solving real-world problems and providing evidence-based, measurable impact to ensure industry momentum and credibility. Staying committed to scaling real, high-quality, verifiable climate action will ensure that the industry stays true to its mission – and plays a value-additive role in the fight against climate change.

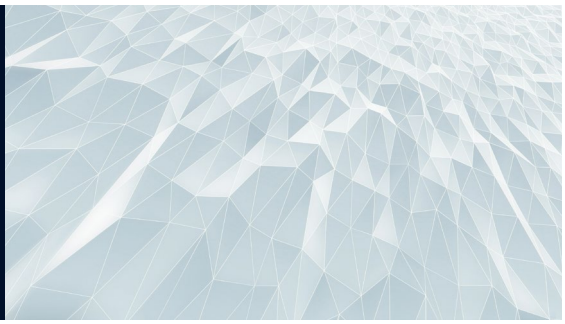
Looking to the future

Real-world use cases will ensure solutions fit demand. Mass adoption of any new tool is driven by effectively meeting demand – or, in other words, solving a problem. Piloting real-world use cases of blockchain-based applications for climate impact provides a critical reality check on the hype cycle of innovation. Putting these applications to the test generates valuable user feedback and ensures solutions are designed to solve the right problems. Builders must, therefore, demonstrate tangible impacts (i.e. reduced CO_2 emissions, hectares of mangroves planted, payments to communities transacted, etc.) through more transparent and auditable reporting structures to improve the legitimacy of, and trust for, blockchain's role in climate solutions.

> **If we can focus on where Web3 can really help us now and not trying to just 'Web3 everything', we will be able to move faster.**
>
> Benoît Clément, Director, Financial Innovation, Verra

A fully digital VCM will demonstrate market-making and growth capabilities. Digitizing the VCM is currently the leading use case for blockchain innovations in the climate space. Key challenges such as market fragmentation, analogue reporting and verification procedures leading to bottlenecks in credit issuance, and limited price discovery have stymied the growth of the VCM for over two decades. In the last three years, a flurry of new enterprises has emerged to lower barriers to entry, provide quality assurance through enhanced traceability and facilitate market-making for greater liquidity. To realize the full benefits of these efficiencies and increased market participation, closer collaboration is needed among registries, carbon standards, verification bodies, scientific communities and blockchain entrepreneurs to construct a mutually beneficial end-to-end digital ecosystem.[35]

> **Five years from now, I think almost every major registry will be blockchain-based. I think most credits will be issued on the blockchain in a tokenized format. And we just won't really see what's going on behind the scenes.**
>
> Alasdair Were, Adviser, IETA



More blockchain-enabled tools to scale the VCM are on the horizon. Fractionalizing verified credits into units smaller than one tonne of CO_2 may support the growth of a retail customer base and embedded application programming interfaces (APIs) into e-commerce solutions. Managing forward contracts on-chain is another emerging trend that may increase liquidity to scale carbon sequestration projects in the years ahead.

Innovation is moving beyond carbon. Following the lessons learned from digitizing the VCM, blockchain innovators are beginning to look beyond carbon markets to help unlock new forms of climate finance and real-world benefits. New digital environmental asset classes (e.g. for biodiversity and ecosystem service credits) and real-world assets (e.g. stablecoins, synthetic tokens, lending protocols) are being developed to capture a wider spectrum of environmental, social and economic benefits. As the technology matures, these products may evolve from composite credits into new markets independent of carbon. In parallel with these new credit types, dMRV technologies are also expanding from focusing on forest assets into new under-documented territories, like aquatic biomes and soil health. Finally, developing new climate databases as digital public goods lays the foundation for greater global coordination on climate action. Ensuring that this data and technical infrastructure remain publicly accessible and open source will enable future design iterations and contextualization to suit specific needs as the climate – and humanity's relationship with it – continue to evolve.

> **Web3 can really help in addressing these global challenges, but to build this new system, well, it will take a bit of time.**
>
> Amy Westervelt, Senior Delivery Lead, EnergyWeb

Appendix

A1 Glossary

Blockchain[36]**:** A distributed ledger technology (DLT) that allows for the permanent, immutable and transparent recording of data and transactions through a cryptographically secure digital database of transactions that are stored on a public or private network.

Climate finance[37]: Refers to local, national or transnational financing – drawn from public, private and alternative sources of financing – that seeks to support mitigation and adaptation actions that will address climate change.

Consensus network: The agreed-upon method that secures a blockchain network to ensure transactions are trusted and validated.

Cryptocurrency (crypto): A digital currency in which transactions are verified and records are maintained by a decentralized system using cryptography rather than a centralized authority**.**

Decentralized autonomous organization (DAO)[38]**:** A general term for a group that uses blockchains and related technologies to coordinate its activities.

Decentralized finance (DeFi): Comprises financial products and services accessible to anyone with an internet connection. DeFi operates without the involvement of banks or any other third-party firms.

Digital public infrastructure (DPI)[39]**:** Refers to solutions and systems that enable the effective provision of essential society-wide functions and services in the public and private sectors.

Layer 1 blockchain[40]**:** A network that acts as infrastructure for other applications, protocols and networks to build on top of.

Measurement, reporting and verification (MRV)[41]**:** Refers to the multi-step process to measure the amount of GHG emissions reduced by a specific mitigation activity, such as reducing emissions from deforestation and forest degradation, over a period of time and report these findings to an accredited third party.

Digital measurement, reporting and verification (dMRV)[42]**:** Software solutions capable of automated data collection, processing, analysis and generation of carbon credits, including validation and verification processes.

Nationally determined contributions (NDCs)[43]**:** A climate action plan to cut emissions and adapt to climate impacts.

Non-fungible token (NFT): A digitally native asset that has been tokenized by blockchain, making it unique and unable to be replicated.

Real-world assets (RWA)[44]: Tangible assets or financial primitives with the potential to serve as collateral in the DeFi industry. The term "real-world assets" emerged in recent years to differentiate cryptocurrencies from traditional financial holdings. Unlike cryptocurrencies that only exist in digital form, RWAs are usually tangible and tied to real-world organizations.

Regenerative finance (ReFi)[45]**:** A group of blockchain-powered projects that emphasize creating systems that distribute economic value back to the environment and communities.

Science Based Targets initiative (SBTi)[46]: Science-Based Target initiatives provide companies with a clearly-defined path to reduce emissions in line with the Paris Agreement goals.

Smart contracts[47]**:** Programs stored on a blockchain that run when predetermined conditions are met. They are typically used to automate the execution of an agreement so that all participants can be immediately certain of the outcome without any intermediary's involvement or time loss. They can also automate a workflow, triggering the next action when conditions are met.

Tokenization[48]**:** The process of transforming ownerships and rights of particular assets into a digital form. By tokenizing, individuals can transform indivisible assets into token forms.

Tragedy of the Commons[49]**:** A situation in which individuals with access to a public resource (also called a common) act in their own interest and, in doing so, ultimately deplete the resource.

Voluntary carbon market (VCM)[50]**:** Where private individuals, corporations and other actors issue, buy and sell carbon credits outside of regulated or mandatory carbon pricing instruments.

Web2[51]**:** The internet as it is known today – with user-generated content in exchange for one's data that is owned by centralized entities.

Web3: A loose term used to define the new decentralized, permissionless internet using blockchain, cryptocurrencies and NFTs that allows the user to control the data instead of a centralized player.

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Acknowledgements

We would like to express our gratitude to the following senior leaders who provided guidance, oversight and thought leadership for this paper.

ReFi leaders interviewed

Luis Felipe Adaime
Founder and Chief Executive Officer, MOSS.Earth

Miles Austin
Chief Executive Officer, Hyphen

Gabriela Chang
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Benoît Clément
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Lucia Gallardo
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Gregory Landua
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Special thanks to the CISA team, members of the Crypto Sustainability Coalition, the CISA Steering Committee, contributing writers and our expert reviewers, namely:

Sadia Ahmed
Climate and Environment Ventures Lead, Deloitte

Nicolas Alexander
Head, Partnerships and Policy, Thallo

Alizee Carli
Director, Strategy and Ecosystem Growth, Casper Association

Kevin Christopher
Founder and Principal, Rockridge Venture Law

Joel Curado
Managing Director, Business Development, Casper Labs

Alison Filler
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Tobias Huber
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Ken Weber
Vice-President and Head, Social Impact and Sustainability, Ripple

Samantha Weinberg
Project Specialist, CISA, World Economic Forum

Production

Studio Miko

Laurence Denmark
Creative Director

Martha Howlett
Editor

Oliver Turner
Designer

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