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STANDALONE REPORT

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ADVANCING BLOCKCHAIN SOLUTIONS
FOR SUSTAINABILITY AND SUSTAINABLE
BLOCKCHAINS



GBBC GSMI 5.0

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GSMI 5.0 IN-DEPTH REPORT

ADVANCING BLOCKCHAIN SOLUTIONS FOR SUSTAINABILITY AND SUSTAINABLE BLOCKCHAINS

INTRODUCTION

We need standards on sustainability:

Core sustainability frameworks point to a broader context of governance, social, and environmental factors that innovations must address to ensure lasting global impact. As developers focus on building innovations that will bring forward the use of blockchain technology to address global sustainability issues, it is fundamental to have a common adherence and understanding on standards. Standards provide resilience for projects, ultimately ensuring innovations are deployed in a responsible and truly impactful manner as they are intended.

This report addresses those activities at the intersection of blockchain technology and sustainability goals. It starts with covering a basic taxonomy of authority bodies and basic applicable rules, followed by a discussion of ways blockchain can advance sustainability projects, and finally a discussion on how the blockchain space itself is taking measures to operate in a sustainable manner.

I. TAXONOMY

Often regulatory frameworks and reporting requirements are crucial for businesses, organizations, and individuals to adopt sustainable practices and undergo necessary behavioral changes in a coordinated way. Entities operating at the intersection of blockchain technology and sustainability are bound to navigate the complex and evolving landscape of regulatory requirements for blockchain technology, and in addition, be compliant with requirements covering their sustainability practices.

It is important to consider the landscape of global authorities setting standards, best practices, and regulatory obligations, in addition to the data and requirements around reporting and disclosures. Public-private partnerships can be fundamental to guiding and establishing reasonable and measured obligations, especially at a global level. There is still a need to address and harmonize fragmented systems and approaches.

Below is a taxonomy of sources of legal, regulatory and quasi-legal authority related to climate and sustainability. In the context of identifying these, it is useful to cover those authorities with the greatest influence globally, having comprehensive coverage of those that affect the greatest number of entities recognizing that each entity will be subject to climate and sustainability rules not included here.

Table 1: Sources of Authority for Sustainability

Level of Authority	Relevance	Examples
Legislation	Legislation takes the form of enacted rules. Its importance is its durability and permanence. This is the realm of authority with the least flexibility for interpretation and change. In the United States, for example, it is harder to pass legislation than issue regulations; but once passed, these laws and statutes are much harder to challenge in courts.	Statutes can cover different jurisdictional levels, ranging from; - Supranational level covering multiple nations (e.g., European Union) Statutes can cover different jurisdictional levels, ranging from; - Supranational level covering multiple nations (e.g., European Union) - National rules (e.g., US federal agencies like the Securities and Exchange Commission) - Political economy levels, where rules apply only to the domain where a specified political economy may have jurisdictional authority (e.g., US states) - Regional authorities (e.g., multistate bodies that regulate how electricity is managed) - Bilateral and multilateral treaties (e.g., MOUs between jurisdictions, acting as contracts among countries to take certain actions)
Regulation	Regulations are pursuant to statutory authority as defined by legislation. They comprise rules with a similar legal effect as legislation, but regulations can be more easily revised or abandoned. Usually government agencies take regulatory actions, often becoming implementing agencies to ensure compliance with the rules put forth. These agencies issue nimble rules that can be enforced quickly, sometimes with severe penalties. The only recourse people may have to resist these rules may be in court, which would be expensive and risky. There may be ample space for interpretation, and the drivers to assist people in compliance may be more behavioral.	Regulations can span federal (country-level), state, or local rules. They include policies, standards, and rules that businesses, organizations, and individuals are obliged to follow. For instance, environmental regulations may limit power plant emissions. Financial regulations may impact the operations of financial institutions from banks, credit unions, insurance companies, etc. Employment regulations may set minimum wages, protections against child labor, and licensing requirements.
Guidance	Guidance is pursuant to regulatory authority. Guidance documents make no enforcement promises. It is assumed that if entities follow the rules announced through guidance, then there will be no enforcement actions against those who conform to their dictate. Due to the fact that guidance has room for interpretation, certain entities may be deemed to be non-compliant even when doing their best to remain in compliance.	Guidance may be announced by industry sector. In some domains, laws and regulations may be too broad, such that guidance from agencies becomes more relevant for the regulated community to take actions (e.g., US Food and Drug Administration setting documentation to submit for different purposes). If entities are considered to be non-compliant with these rules, there is a risk of being sued (e.g., SEC enforcement letters to blockchain and digital assets startups).

Quasi-Regulatory: International bodies	International bodies tend to work with governments to enforce treaties and other international rules. Representatives of various nations and supranational entities come together to attempt to set rules and standards.	Governments can work with international organizations like the United Nations to enforce global treaties and rules. The United Nations Framework on Climate Change (UNFCCC) has established the main international agreement on climate change.
Quasi-Regulatory: Voluntary Standards Bodies	Industry bodies and professional associations can set rules at a sub-legal level, which can be presented as voluntary standards and frameworks for a variety of activities. These quasi-regulatory voluntary standards bodies represent a wide array of different types of distributed geographical, industry, and technical expertise, creating common rules and inviting relevant stakeholders to follow them. These organizations are not backed up by government power, so they are not in a position to enforce their system of rules and standards with government authority. Instead, they rely on the voluntary consensus of the community as authority. They are considered, nevertheless high reputation organizations, and it is in the best interest of entities operating in a given industry to follow their standards where relevant, as a stamp of legitimacy. While there is no obligation to follow their rules, often stakeholders do choose to follow them, giving these organizations de facto power that may resemble that of legal authorities. These standards bodies can be highly influential in establishing authorization of methodologies, protocols, and instruction sets. The aim of these rules can be to preempt regulatory action to follow. If industry-focused bodies can show that their standards are widely adopted, government agencies may then be compelled to utilize those standards as a default premise to set regulatory requirements. If a significant portion, or a majority, of an industry adopts a voluntary standard by consensus, then any ensuing regulatory developments that may contradict this standard would be very difficult to enforce. In this way, consensus-based standards bodies can be a way for industry to take part in shaping the rules it will be held subject to. Moreover, to extent relevant conditions may apply, consensus-based standards bodies can merge or collaborate with regulatory bodies to take advantage of safe harbors.	International standards bodies (e.g., ISO, ASTM, UL, accounting standards), may have a level of authority that is not considered legal and does not come directly from governments yet is still considered mandatory to operate in a certain way. Industry-focused groups also include voluntary standards-setters focused on environmental space at an international level (e.g., International Sustainability Standards Board), standards bodies focused on a specific environmental activity (e.g., Verra, Gold Standard, EcoRegistry for carbon markets), or standards operating at a country level (e.g., US voluntary consensus standards as defined by the Department of Energy).

Data disclosures ensure transparency and accountability for stakeholders. Hence, several accounting frameworks for sustainability have arisen in the context of the importance of sustainability accounting, which involves the collection, analysis, and reporting of social and environmental impacts of businesses. Sustainability frameworks and requirements set a path toward companies to manage risks, monitor progress toward net-zero and other sustainability goals, and ultimately raise their reputation and brand image.

Particularly in development sectors, it can be difficult to track activity on the ground when there are various systems in use, especially when there is still a need for basic infrastructure to move beyond manual systems and adopt blockchain solutions. There is still a need for technical integrations and capacity building, but standards and requirements can help pave the way toward necessary measures and compliance.

Below is a mapping of major global, or globally relevant, requirements for sustainability. While these frameworks range from mandatory to voluntary, and span several jurisdictions, there still may remain inconsistencies in reporting due to different requirements, and actions are being taken toward consolidation and harmonization.

Table 2: Global Sustainability Requirements and Standards

Requirement	Description	Jurisdiction
EU Corporate Sustainability Reporting Directive (CSRD)	Under this European sustainability reporting program, companies are mandated to disclose standardized and comprehensive data on their environmental, social, and governance (ESG) impact. Sustainability reporting is put on par with financial reporting.	EU, with global implications
EU Green Deal	Composite of over 12 regulations related to sustainability	EU, with global implications
EU Emissions Trading System (ETS), and other ETS around the world	Establishes a “a cap-and-trade” system that sets a limit (cap) on total greenhouse gas emissions permitted for certain sectors, and allowances for emitters that can be bought and sold. This creates an economic incentive to reduce emissions, such that entities that pollute less can sell their unused allowances in this marketplace. Out of a larger number of active emissions trading systems, the EU ETS is the oldest and most impactful by size and scope (e.g., German ETS with carve outs for the auto industry, UK ETS modeled after EU with carve outs for certain industry interests), dwarfing the size of other voluntary and compliance markets around the world. Most of these markets don't allow voluntary offsets issued in other contexts to be integrated into their systems, with few exceptions (e.g., South African ETS may permitting certain exceptions).	EU (or other jurisdiction specified), with global implications

Paris Agreement	Legally binding climate change international treaty, which was adopted in 2015 and came into force in 2016, and falls under the United Nations Framework Convention on Climate Change (UNFCCC). This is the first instance where all nations agree to cooperate at scale on climate action. This involves countries working to adapt to the impacts of climate change, reducing emissions, strengthen commitments, and provide climate financing for developing nations. The goal is to limit global warming to significantly below 2°C over pre-industrial levels, in addition to taking all possible actions to limit temperature rising below 1.5°C over pre-industrial levels. Article 6 of the Paris Agreement allows countries to collaborate for the reduction of carbon emissions. This involves the growth of carbon markets, standards, and registries. As Article 6 comes into force, voluntary carbon markets may surpass the size of the EU ETS.	Global
US Securities and Exchange Commission (SEC) Climate Disclosure Rule	The SEC Climate Disclosure Rule requires public companies to include climate-related disclosures in their annual reports and registration statements. Companies must specifically disclose data that can materially impact their core businesses and investor decisions. The purpose of this rule is to provide investors with standard information to guide them in making informed decisions related to identifying investment opportunities and risk management. These disclosures include climate-related risks and related governance actions, financial effects of extreme weather or natural conditions, greenhouse gas emissions, assessment and management of climate-related risks, and actions taken to account for such climate-related risks.	United States, with global implications
Carbon Disclosure Project (CDP)	International carbon disclosure reporting program to incentivize companies, including suppliers and business relationships, to disclose their emissions and other climate-related information to key stakeholders and investors.	Global
Supply Chain Due Diligence Laws	Laws like the EU Corporate Sustainability Due Diligence Directive (CSDDD), Germany's Supply Chain Due Diligence Act, the UK Modern Slavery Act, Australia's Modern Slavery Act, the EU's Forced Labor Ban, and the US Tariff Act of 1930, set requirements mandating companies to assess and address the environmental (e.g., transition plans) and human rights risks across their supply chains. Even the suspicion of forced labor in a shipment can jeopardize it being mandated to be sent back. These requirements are meant to ensure companies can prove they are taking action to prevent these risks.	Specified jurisdictions, with global implications
California's Climate Disclosure Bill	This law sets requirements for climate disclosures for companies with over \$ 1 billion in annual revenues doing business in the US state of California.	US state of California, with global implications
Benefit Corporation (B-Corporation) Structure	The B-Corporation establishes a scoring framework applied to sustainability and governance practices. This provides a certification granted to a for-profit company for meeting high social and environmental standards, especially with respect to transparency on practices and outputs, accountability, governance structure, and workforce.	Global

International Sustainability Standards Board (ISSB)/ Sustainability Accounting Standards Board (SASB) / Task Force on Climate-Related Financial Disclosures (TCFD) Recommendations	The International Financial Reporting Standards (IFRS), which set a global standard for accounting rules and financial reporting to ensure consistency and comparability, has released the IFRS Sustainability Disclosure Standards, which are developed and approved by the International Sustainability Standards Board (ISSB). SASB sets standards that specify sustainability information disclosures that are financially material across 77 industries. These standards are being integrated at the level of the International Sustainability Standards Board (ISSB). TCFD recommendations provide guidance on information that companies should disclose on financial risks related to climate change. TCFD recommendations are also being integrated at the level of ISSB.	Global
Global Reporting Initiative (GRI) Standards	GRI is an international independent standards organization that provides a modular framework including universal, sector-specific, and topic-focused standards meant to reflect global best practices for sustainability reporting. These standards are a tool for businesses, governments, and other entities to better understand and reflect their impacts related to climate change, human rights, and corruption issues.	Global
Science Based Targets Initiative (SBTI)	Provides standards and guidance for climate action specific to certain industries, with the goal of enabling a net-zero economy and embracing innovation to drive sustainable growth. These best practices are based on scientific research and guide companies and organizations to set and meet ambitious emissions reduction targets.	Global
Integrity Council for the Voluntary Carbon Market (ICVCM) principles	Principles to incentivize rules on what comprises a high-quality carbon credit, with ethical and environmental validity considerations for minting carbon credits. ICVCM takes responsibility for ensuring carbon credit quality on the supply side, ensuring the integrity of carbon credits.	Global
Verra	Verra's Verified Carbon Standard (VCS) program validates and credits greenhouse gas emissions. Projects and programs that register with VCS, after completing a development and assessment process, are issued unique carbon credits authorized for trading in global carbon markets.	Global
"Blue Sky" Campaign	Air pollution reduction through stricter emissions standards and fostering reliance on cleaner sources of energy.	China, with global implications
Ecodesign Regulations	Rules like the European Ecodesign Directive, which was significantly expanded into the Ecodesign for Sustainable Products Regulation (ESPR), as part of the Sustainable Products Initiative, and the 2020 Circular Economy Action Plan, are mandating the adherence to sustainable design principles for companies' products. These principles are aimed to minimize environmental impacts throughout the lifecycle with elements like circularity, responsible energy usage, minimizing waste, resource efficiency, and other sustainable practices. The US (e.g., Energy STAR certification for energy efficiency), Japan, South Korea, Brazil, and India are also increasingly considering and putting in place ecodesign principles.	Specified jurisdictions, with global implications

Regulations	Rules that protect biodiversity are being set across jurisdictions, including the US Endangered Species Act of 1973 which prohibits commercializing endangered species and requires recovery plans to protect critical habitat areas. Biodiversity offsetting policies also require entities to compensate for any negative impacts of their activities on biodiversity by preserving, restoring, and enhancing biodiversity elsewhere. France, for instance, has required biodiversity disclosures and vigilance plans for companies with over 500 employees. These companies must set plans to identify biodiversity risks, carry out ecosystem impact assessments, and describe mitigation actions. In addition, international biodiversity treaties include the Convention on Biological Diversity (CBD), the Convention on Migratory Species (CMS), and the Convention on International Trade in Endangered Species (CITES). Finally, the Taskforce on Nature-related Financial Disclosures (TNFD) has established recommendations for companies and organizations to report and take action based on nature-related impacts, risks, and opportunities.	Specified jurisdictions, with global implications
Greenwashing Prevention	Rules and requirements from governments and industry bodies are underway to address deceptive environmental marketing and misleading sustainability claims by companies and organizations. This requires transparency and greater accuracy in messaging about environmental practices (e.g., making specific claims, with supporting evidence, and verifications). These rules also support companies to establish an anti-greenwashing strategy. Anti-greenwashing regulation includes the 2024 EU Directive on Green Claims, the UK Green Claims Code, the Australia Green Claims Code, components of the US SEC Climate Risk and Emissions Disclosure Rules, and similar approaches in Canada, France, and South Korea.	Specified jurisdictions, with global implications

II. BLOCKCHAIN TO ADVANCE SUSTAINABILITY GOALS

Emerging technologies including blockchain can greatly help address climate change concerns and facilitate compliance with increasing sustainability requirements. Blockchain provides a toolset to solve business problems in ways that are in compliance with regulations and environmentally friendly best practices. These solutions are increasingly relevant as nation-states are taking steps to comply with the Paris Agreement commitments and turning to technology to assist them to tackle the most complex and urgent issues of taking climate action, ensuring transition plans, and reducing emissions.

Moreover, the ability to implement these technology tools depends on legal, regulatory, and voluntary standard landscapes where companies and organizations are operating. The legal context could bring challenges that blockchain technology can help overcome, becoming a tool to support competitive advantages by facilitating compliance with requirements. Reporting, which has largely focused on carbon emissions, can be difficult to accurately calculate across direct Scope 1 to indirect Scope 3 emissions, and subsequently report to the public. Emerging technologies including blockchain can help with this task, in the context of standardized reporting mechanisms still in development.

Foundational Issues for the Circular Economy:

In the context of climate change, land-system change is one of several planetary boundaries where humanity is living outside of a safe operating space. Changes in the use of land, largely from forests

to agricultural land, have affected climate by altering the carbon dioxide level concentrations, and impacting biodiversity, freshwater, and Earth's surface reflectivity. Earth's biggest systems that trap carbon (forests/rainforests/soil) are no longer trapping as much as necessary. Risks to humans range from health, natural disasters and extreme weather, and impacts on infrastructure.

Permacultures, for instance, introduce an ethical and holistic, ethical approach to land management and settlement that draws on natural ecosystem dynamics that are inherently localized. The goal is to improve sustainability practices and reduce waste, while increasing efficiency and transparency of supply chains, and verifying that resources are adequately sourced, managed, and recycled or repurposed. Blockchain technology can track data to ensure effective mitigation practices, with an unprecedented level of transparency to monitor short- and long-term impacts. NFTs and incentive structures that affect bottom lines can further advance a range of best practices to combat climate change and its effects. Ultimately, blockchain technology can record data, impact, and align incentives toward responsible use of resources at a local level, even as granular as micro communities or individuals.

Sustainable Housing: There is opportunity to utilize localized resources to build multi-family units, such as wood from trees that get replanted with sustainable considerations. Blockchain technology can ensure the provenance of materials, ensuring responsible sourcing, ecosystem conservation practices, and guaranteeing that there is no deforestation impact.

Food Supply: Localized, and even hyper-localized resources can support the circular and local economy with fewer emissions. Incentivizing local supply and demand can ultimately reduce costs, benefitting small and medium businesses and consumers. This can improve levels inclusion especially in the context of global food shortages. Blockchain technology can track these circular economies, including local supply chains and validating responsible agricultural practices (e.g., use of chemicals and pesticides). This transparency and efficiency can help ensure adequate stable food supplies to meet the needs of a given community, ultimately bringing more integrity into the food industry. An added benefit would be that shorter shipment times and a shorter shelf life prior to consumption preserves higher nutritional density and can support health outcomes. Incentive structures can also be created for activities like composting, to support further local food production.

Waste Management: Waste to energy systems, where waste produced by a household can be utilized to produce power, can provide monetary benefits for households and be verified with blockchain and tokenized assets. Incentive structures can also reward households that demonstrate more sustainable behaviors with their waste, such as NFTs or other tokens to enable additional purchases or other benefits. IoT technologies including sensors can detect areas where waste is being managed more responsibly

Water Usage: Much like with carbon markets, blockchain technology can facilitate water trading as an exchange of water rights, or allocations, between buyers and sellers. Blockchain can be useful to make trading activity more efficient, helping match buyers and sellers, increasing competition to lower prices. Added transparency can address concerns over provenance issues and improve trust. Moreover, as wastewater can be treated and reutilized to support a permaculture, tracking and tracing mechanisms can enhance the validity, scalability, and impact of these processes.

Renewable Energy: Today, consumers usually have one major choice to purchase power from state-run utilities. Other choices, such as co-location of solar farms or owning solar panels, are

often distant second choices, and access to wholesale markets to purchase power from several generators can be very limited. Blockchain can facilitate a transition away from dependence on a small number of massively produced fossil fuel sources, to reliance on numerous renewable energy sources, each of which can be small in its production capacity.

Blockchain technology can be an effective accounting system for grid management for renewable energies, with the necessary pricing flexibility to adapt to changing supply and demand dynamics. Tokenization can facilitate local energy production and trading, so that individual households can benefit economically from excess energy sales. Competitive markets for energy can permit buyers to bid on offerings by sellers. Blockchain technology can make these markets more efficient and transparent, enhancing opportunities for individuals to competitively bid for electrical generating capacity as buyers on wholesale markets (e.g., deregulated energy markets in some US states), or purchase energy in retail markets, allowing for price negotiations for renewable rates. Microgrids are also increasing in popularity, with opportunities to provide energy back into the main grid (e.g., powering electric vehicles).

With blockchain, Pricing can be made more transparent based on the competitive landscape, energy projects' characteristics, and aspects like scope and cost. Smart contracts can limit credit risk and collateral requirements, putting funds on escrow and ensuring delivery of energy upon payment. Certificates of origin of energy, as well as renewable energy certificates (RECs) can also be validated by, unbundled, and sold separately in marketplaces. Access to energy subsidies can also be facilitated in relevant jurisdictions that authorize RECs, especially for cases where renewable energies may be more expensive (e.g., off-shore wind). Incentive structures enabled by blockchain can also provide tools to significantly increase sales, tracing, and reporting of renewable energies. Finally, blockchain can facilitate the implementation of legal orders with partial oversight over energy markets that align incentives toward renewable capacity production.

Selected Examples of Blockchain Solutions for Sustainability

Blockchain technology can benefit sustainability initiatives with transparency of data, tokenization, and advancing the interests of the Global South.

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Satva Trust – Carbon Data for Global Shipping (Data Transparency)

Satva Trust is a technology company that leverages AI and machine learning to provide independent, auditable, and consistent data on fuel consumption and carbon emissions in the global shipping industry. Their platform offers unique insights that help stakeholders, including banks, insurers, and shipowners, make better business decisions by assessing risks associated with fuel use and emissions performance.

Satva Trust ensures data transparency and traceability using the blockchain, enabling users to compare their emissions performance with peers globally and price lending or insurance products based on emissions performance. This innovative approach supports the shipping industry's decarbonization efforts and promotes sustainable practices.

Plastic Bank – Transparency for Recycling (Global South, Data Transparency, Tokenization)

Plastic Bank is a social fintech company that aims to tackle plastic pollution and poverty by incentivizing the collection of plastic waste. They support the Global South through their operations

in regions with high levels of plastic pollution and poverty, such as the Philippines, Indonesia, Brazil, and Egypt. They establish collection branches where community members can exchange plastic waste for money and social benefits, such as grocery vouchers, health insurance, and life insurance. This approach helps to alleviate poverty while cleaning up the environment.

Plastic Bank uses blockchain technology to ensure data transparency and verification that allows for traceability and accountability, ensuring that every piece of plastic collected is tracked from collection to recycling. Plastic Bank's tokenization process involves converting physical plastic waste into digital tokens, which can be tracked and verified on the blockchain. This ensures that the plastic waste is properly accounted for and that the social and environmental impacts are transparent and measurable.

Ava Labs – Sustainable Blockchain (Tokenization, Data Transparency, Global South)

Ava Labs, creators of the Avalanche blockchain platform, are promoting sustainability by offering an energy-efficient network which reduces environmental impact of networks run on this technology. Unlike traditional proof-of-work systems that consume large amounts of energy, Avalanche uses an innovative consensus mechanism called repeated random sub-sampling to validate transactions. This solution has significantly lower energy usage compared to networks like Bitcoin. For instance, a 2022 [study](#) highlighted that Avalanche's proof-of-stake network uses a minuscule fraction (0.0005%) of the energy consumed by Bitcoin's network.

The platform enables tailored tokenization, allowing real-world assets to be represented digitally on the blockchain. This capability enhances transparency in data sharing and makes transactions more efficient. This can be particularly beneficial for countries in the Global South, as they open up access to decentralized financial services and create new economic opportunities.

In addition, Ava Labs offers AvaCloud, a no-code, customizable platform that lets users develop blockchain solutions tailored to their needs without requiring advanced technical skills. This accessibility encourages innovation in areas like renewable energy trading, tracking carbon credits, and creating transparent supply chains, which can contribute to sustainability efforts globally.

Hedera – Sustainable Blockchain (Tokenization, Data Transparency, Global South)

Hedera Hashgraph is advancing sustainability through its energy-efficient ledger technology and by facilitating the tokenization of environmental assets. To this end, Hedera uses the Hedera Guardian, an open-source tool that standardizes and streamlines the creation and management of digital assets used for carbon credits and renewable energy certificates.

The Guardian simplifies the process of developing ESG assets by incorporating policy templates and automating data collection and verification, often integrating with IoT devices. This enhances transparency and ensures compliance with regulatory standards, reducing the risk of fraud in environmental markets.

Facilitating and streamlining of the management of environmental assets help organizations efficiently trade and track these assets on Hedera's network. The platform is globally accessible, and its open-source nature means that it can be adopted by emerging markets in the Global South, thus aiding these regions in participating in global sustainability initiatives and attracting investment for environmental projects.

Ripple Impact – Sustainable Blockchain (Global South, Tokenization, Data Transparency)

Ripple Impact is using the XRP Ledger (XRPL) to support sustainability and foster economic development. The XRPL operates on an eco-friendly consensus mechanism that avoids energy-intensive mining, thus maintaining high efficiency without compromising security or decentralization.

One of Ripple's significant contributions is in the space of cross-border payments. Traditional international money transfers can be costly and slow, affecting over 272 million migrants worldwide who rely on remittances. Ripple's technology offers a solution by enabling faster, more reliable, and more affordable transactions through their network. This is particularly important for individuals and economies in emerging markets, enabling greater connectivity, and ease of cash transfers on a safe and accessible platform.

The XRPL also supports applications such as CBDCs and NFTs, which can promote financial inclusion and create opportunities for economic growth when implemented effectively.

BTG Pactual – Nature-Based Solutions (Global South, Data Transparency)

Brazilian financial institution BTG Pactual's Timberland Investment Group is leading efforts in Latin America to restore and reforest land, using advanced technologies to support sustainability. Partnering with Meta, they are employing open-source data and artificial intelligence models developed with the World Resources Institute to monitor forests. These tools allow for detailed mapping of tree canopies, even identifying individual trees on a global scale. Making this data publicly available enhances transparency and can aid various stakeholders in their efforts to advance in carbon markets and reforestation efforts.

The aim of the project is to generate carbon removal credits by addressing deforestation in critical regions, rehabilitating degraded lands and their biodiversity. Due to accurate monitoring, BTG Pactual can ensure precise carbon accounting, thus strengthening the credibility of carbon markets - a feature essential to their functioning and growth.

Beyond environmental restoration, the initiative supports local communities, by creating jobs and encouraging sustainable economic activities such as honey production, which benefits from the restored ecosystems. By combining technological innovation with sustainable practices and supporting structures for the emerging bioeconomy, the project combines action for environmental and social SDGs within the Global South.

Algorand - Digital Health Passport: (Data Transparency, Global South)

Algorand Foundation's India initiative has collaborated with Lok Swasthya SEWA to launch a Digital Health Passport based on the AlgoBharat blockchain technology. This innovative solution aims to enhance healthcare access by providing secure, immutable records of verified health credentials. The Digital Health Passport allows users to quickly access critical health benefits and social safety net programs while also helping SEWA Shakti Kendras scale services based on individual household requirements. This initiative particularly benefits working women and their families, promoting economic empowerment and self-reliance.

The Algorand Digital Health Passport utilizes blockchain for transparent data management. By creating immutable records of health credentials, it ensures data integrity and security, complying with India's new Personal Identifiable Information regulations. This use case advances the interests of the Global South by improving healthcare access and empowering women workers in India.

Hyphen - Trust in Carbon Markets: (Transparent data, Global South)

Hyphen collaborated with LI-COR to develop a revolutionary technology for greenhouse gas (GHG) monitoring in carbon markets. This collaboration integrates LI-COR's eddy covariance flux measurement systems with Hyphen's proprietary atmospheric-based digital monitoring, reporting, and verification (aMRV) software. The result is a robust hardware-software combination that automates the entire process of issuing high-quality carbon credits. This solution offers real-time, precision quantification of GHG fluxes across various sectors, including nature-based solutions, agriculture, oil and gas production, and waste management.

This use case leverages blockchain for transparent data by providing real-time, accurate quantification of GHG fluxes. The solution enhances the integrity of carbon markets by improving transparency and trust through automated, blockchain-based processes. While not explicitly mentioned, this technology could potentially benefit the Global South by providing more accurate and trustworthy carbon credit verification for projects in developing countries.

Nuklai - Smart Farming: (Transparent data, Tokenization, Global South)

Nuklai, an on-chain smart data platform, has collaborated with peaq, a layer-1 blockchain for decentralized physical infrastructure networks (DePINs), to improve AI and data monetization capabilities for DePINs, beginning with Farmsent, a global Web3 marketplace for farmers. This integration aims to leverage data from over 400,000 devices within the peaq ecosystem to provide quality datasets and industry insights for smart farming. With more than 160,000 farmers registered, Farmsent leverages blockchain technology to streamline the food supply chain by cutting costs, enhancing transparency, and eliminating middlemen.

This use case relies on blockchain for transparent data and tokenization, by creating decentralized product passports (DePPs) that record and verify the journey of agricultural products. It also incorporates tokenization through the potential for data monetization opportunities within the ecosystem. The initiative advances the interests of the Global South by empowering small farmers, enhancing food security, and providing valuable insights for a more data-driven agricultural future.

AgroWeb3 – Sustainable Agricultural Ecosystem (Global South, Data Transparency, Tokenization)

With the support of the Inter-American Development Bank, AgroWeb3 is a project built on the LACChain blockchain, to develop an ecosystem that relies on verifiable digital credentials, specifically for managing activities with economic and environmental assets for smallholder farmers across developing countries. The aim is to improve transparency and accountability for food systems, in a way that ensures financial inclusion and empowers smallholder farmers by facilitating their access to the digital economy.

AgroWeb3 enables market linkages, improves visibility of supply chains, and facilitates funding – particularly microcredit access for farmers to scale their operations. Smallholder farmers can be more engaged and active decision makers, and greater beneficiaries of economic activity, across the agricultural value chain. Blockchain technology facilitates transparent tracking of agricultural produce in ways that support fair trade and increase buyers' trust. Decentralized identity solutions for farmers can enable greater access to financing and a wide range of services, particularly with a self-sovereign model in which they can own and monetize their data. Farmers can also participate in carbon credit markets to boost their income for adopting sustainable practices.

III. NET ZERO APPROACH FOR BLOCKCHAIN

As blockchain technology is being utilized to help other sectors meet sustainability requirements, the blockchain space itself must address these issues as an industry. It is important to consider that using blockchain as a solution to advance sustainability goals in other sectors also brings tradeoffs, defined by the energy use and sustainability factors of the blockchain being utilized. Just like in any other industry, the blockchain space also has to address sustainability requirements, especially as defined by carbon emissions and reporting requirements. Addressing these issues is also subject to legal, regulatory, and other requirements, which are important to determine and comply with as the space matures.

In most cases, blockchain activities can couple initiatives to decarbonize their activities over time with tokenized carbon credits to address residual emissions. Yet as for calculating past emissions, and current emissions for reporting purposes, there is a significant amount of nuance.

Layer 1 blockchains, which refer to the foundational level of blockchain architecture on which other applications are built, must determine the costs and utility tradeoffs, and make sure they are addressing sustainability concerns. Reducing and controlling emissions is a way to prevent these technologies from expanding sustainability issues across the broad array of applications that are built on them. While the Bitcoin network has been known to utilize significant amounts of energy with its proof-of-work validation mechanism, Ethereum got past this issue when it transitioned from proof-of-work to proof-of-stake and reduced an estimated 99.9% of emissions. Therefore, it is important to consider that not all blockchains utilize the same consensus mechanisms, which leads to different sustainability issues across their respective networks.

Industry communications and messaging on sustainability have yet to be made clear across the blockchain space; yet there has been significant progress. Several blockchain networks, for instance, that have positioned themselves for enterprise use, have also developed energy efficient operations and ambitious net-zero goals.

Ensuring the sustainability of blockchain technology as an industry starts with a clear methodology to measure environmental impacts across blockchain networks. This points to the need to ensure the data to be collected, reported, and monitored. When it comes to carbon emissions, which are the major concern, it is important to consistently define what activities comprise direct and indirect emissions according to generally accepted and standardized convention:

- Scope 1: Direct emissions from operations owned and controlled by an entity.
 - o For blockchains, in most cases there are very few, if any direct emissions. In some cases, however, there may be emissions resulting from direct operations at the miner level. If Bitcoin have ownership of their power generation in terms of equity and operational control, then they produce Scope 1 emissions. Miners may purchase their source of energy to generate the electricity that powers their mining activities. In this case, the power generation is part of the miner's assets.
- Scope 2: Indirect emissions from energy purchased by an entity.
 - o For blockchains, Scope 2 is essential, as it is where most of the action is with respect to emissions. The bulk of these emissions are Scope 2. It points to activity at the node level, referring to the electricity purchased (not controlled at the source) to power operations. Nodes

utilizing computational electricity to run a network make up the core source of emissions for the entire blockchain and digital assets space.

- o Geographical insight on nodes is important, as depending on the energy grid utilized and the emissions associated with it, a node in Africa may not have the same emissions per transaction as a node operating out of North America. Electric grid coefficients for different countries, at a subnational region, or at the utility level, can be utilized to measure this data at increasingly granular levels.
- o It may also be important to understand the supply and real estate related to carbon emissions. The buildings and physical infrastructure where energy is generated may have an impact on emissions. This can be estimated with insight on embedded emissions in building materials, though it may not always be relevant.
- Scope 3: Indirect emissions across an entity's value chain.
 - o For blockchains, this can refer to the emissions of a chain that builds on a separate main chain, a Layer 1. Layer 1 emissions flow through to Layer 2 that runs on a Layer 1, as purchased goods or services, which can be accounted for as Scope 3 in the value chain. Yet questions remain on how to calculate the exact portion of Layer 1 emissions to allocate to Layer 2 activities and consider Scope 3 emissions for that very Layer 2.

Table 3: Net Zero Approach for Blockchain Networks

Chain	Consensus Mechanism	Approach to Scope 1 emissions	Approach Approach to Scope 2 emissions	Approach to Scope 3 emissions
Ethereum - pre merge	Proof-of-Work	function of miners producing energy in-house (trivial)	nodes providing their computational electricity to run a network	Portion of energy from sidechains & other activities on separate chains that runs on Ethereum
Ethereum - post merge	Proof-of-Stake	function of miners producing energy in-house (trivial)	nodes providing their computational electricity to run a network	Portion of energy from sidechains & other activities on separate chains that runs on Ethereum
Bitcoin	Proof-of-Work	function of miners producing energy in-house (trivial), in addition to a potential special case where a historical portion of Scope 2 may be considered Scope 1	nodes providing their computational electricity to run a network	Portion of energy from sidechains & other activities on separate chains that runs on the Bitcoin blockchain
Sidechains / Layer 2	Proof-of-Stake - aligned with that of the main Layer 1 chain on which side chain runs, considered as purchased good or service	function of miners producing energy in-house (trivial)	Sidechain nodes running sidechain network	Layer 1 emissions flow through to Layer 2 as purchased goods/services within Scope 3. Portion of Layer 1 emissions goes to Layer 2's S3

Digital assets have certain unique characteristics that can present challenges for consistent measurement and reporting of emissions. Existing measurement frameworks don't necessarily incorporate how emissions can and should be measured as starting point. When considering emissions per transaction, these can generally be considered Scope 2 or Scope 3, depending on the design of a network and the nature of its operations. The vast majority of blockchain digital asset operations will interplay between Scope 2 and Scope 3 in different ways, where one chain's Scope 2 can be another chain's Scope 3 emissions. It is necessary to have accurate accounting for all these activities.

It is important to define what net zero means in the context of a given blockchain network and its operations, given the wide array of issues encountered on reporting emissions, and potential actions to take to address those issues.

- **Measurement:** Blockchain enables increased granularity when it comes to emissions and activities (e.g., automating emissions analysis and data stored on chain). Moreover, insights extracting data recorded on blockchains can also be used for emission metrics.
- **Reporting:** Voluntary standards and reporting frameworks can be adopted by blockchain providers, which can demonstrate adherence to existing requirements for climate reporting in addition to climate impact investing initiatives. Yet there may still be gaps in how standards are written and how emissions are generated by blockchain networks, such that there may be a possibility to make claims that are not supported by real world impacts.
- **Regulatory Requirements:** As financial entities are being required to report on emissions (e.g., EU MiCA regulation establishing emissions reporting requirements for financial companies, Greenhouse Gas Protocol and its approaches, standards), decisions to purchase digital assets are increasingly tied to regulatory drivers to understand the nature of underlying emissions.

There are several approaches to calculate a network's emissions, and existing methodologies have achieved a certain level of standardization to calculate and measure emissions:

- Cambridge Center for Alternative Finance - Bitcoin & Ethereum Emissions Calculations: <https://ccaf.io/cbnsi/cbeci/ghg/methodology>
- Climate Action Data Trust: <https://climateactiondata.org/how-blockchain-technology-addresses-the-double-counting-of-carbon-emissions/>
- Crypto Carbon Ratings Institute (CCRI): <https://carbon-ratings.com/dl/whitepaper-mica-methods-2024>
- Rocky Mountain Institute: https://rmi.org/wp-content/uploads/2022/02/principles_for_blockchain_based_emissions_reporting.pdf
- Societe Generale: https://www.sgforge.com/wp-content/uploads/2023/11/SGF_Carbon-footprint-report_2023-11-20.pdf
- South Pole: <https://www.southpole.com/blog/accounting-for-the-climate-impacts-of-cryptocurrency>

While these methodologies are a good starting point, there may still be gaps, especially when it comes to sidechains - blockchain networks that connect to a separate main blockchain yet operate independently from it – or a wide range of activities that are built on different Layer 1 protocols. Open questions remain, numbered below, followed by recommended considerations for moving forward in the space:

Open Questions:

1. Should each node have its own location-based emission factors to consider for Scope 2?
2. While there are global trajectories, it may be unclear how a new sector like blockchain, and the various network operation designs, can fit into those trajectories
3. For blockchains that benefit from the emissions reductions from the Ethereum Merge, can they take credit for future emissions that didn't occur?
4. Are there any privacy issues that should be taken into account when utilizing geographical insight on nodes for the purpose of calculating emissions?
5. What additional activities is a Layer 1 chain enabling in other sectors, and how can the chain's activities be utilized to help transition to net zero across the value chain?
6. How does a change in one place of the value chain flow through the blockchain and digital assets space as a whole, and how should emissions be calculated and allocated to the designated stakeholders adequately?
7. How can these changes fit within a normal net zero trajectory, to align with broader emission reduction goals?

Recommendations/Considerations:

1. Define sustainability-focused activities for the sector as a whole, to facilitate better net-zero alignment
2. Develop a more granular approach to metrics, to confront increasing greenwashing concerns.
3. Optimize systems & controls around performance assessments in addition to methodologies.
4. A sector wide approach to metrics should also consider data at a granular level in addition to high level data.
5. Refer to existing reporting frameworks and methodologies available for reporting on emissions, providing granular data to the extent possible.
6. If emissions are avoided (e.g., building on a more energy efficient system, or benefitting from the Ethereum Merge's reduction in emissions), consider if that can be considered a part of a net zero strategy
7. Consider to what extent activities outside the blockchain and digital assets space may play in the discussion of net zero alignment and transition plans
8. Identify additional activities beyond mining and transactions that may have an impact on emissions. Reducing emissions in additional activities in exchange for value from mining or transactions may be beneficial.
9. Identify these additional core activities that can create value in chains, and can be used to allocate emissions fairly across participants.
10. Define what the technology is being used for, and implications for offsetting approaches for Scope 3.
11. Consider a consistent approach for measurement and reporting in cases where one chain's Scope 2 is another chain's Scope 3 emissions.
12. Define how existing methodologies for calculating emissions can fit into existing net zero pathways and identify gaps. Define to the extent possible where gaps may potentially align with requirements for emissions reporting.

13. Be transparent regarding prior practices on emissions calculation, especially if different from current approaches, explain progress and evolution of calculations, and disclose additional issues that need to be considered.

CONCLUSION: A FRAMEWORK FOR BUILDING AND MAINTAINING A SUSTAINABILITY PROOF BLOCKCHAIN ECOSYSTEM:

The development of any blockchain enabled sustainability application requires a careful thought around the key success factors that helps cement its posture and capability to navigate and overcome historical challenges, and particularly inaccurate accounting and reporting of carbon and gas emissions and decarbonization efforts.

A framework that considers the following key aspects can be beneficial for a developing sustainability proof blockchain ecosystem:

- 1. Transparency:** despite the blockchain promise and reality of operating on distributed ledger technologies, making it tamper proof and transparent by design, there are still ways to avoid full transparency. For example, for certain hybrid models sourcing and collecting data may involve manual ways such as feeding data initially on spreadsheets, and then transferring those to the sustainability blockchain application either manually or using AI which may present a risk of loss or evasion of fully reporting on sustainability data. Therefore, mechanisms that allows for a comprehensive identification of the key sources of information, value and inputs that the blockchain users, beneficiaries, regulators and investors can rely on to understand how emissions and decarbonization data is collected, captured, synthesized, processed, reported and disseminated to the concerned stakeholders is fundamental. This also requires recognizing the importance of adopting some of the world's leading sustainability standards and frameworks, while noting the necessity for customization according to the specific circumstances of the applications working environment. For example, places where weak communication infrastructure and services exist may require sustainability blockchain applications be capable to operate with hybrid connectivity modes to ease the collection and capturing of emissions and decarbonization data on chain.
- 2. Trust:** building upon the transparency by design outcomes, a reliable and trusted route is possible if the data infrastructure is built in an accessible way that showcase the emissions and decarbonization journey from start to end to the concerned stakeholders. Moreover, devising a clear set of metrics throughout this journey becomes crucial for the concerned stakeholders, as it will act as a benchmark for measuring progress and improvement in achieving sustainability targets over the long run.
- 3. Accountability:** assigning clear roles and responsibilities for teams and professionals involved in the emissions tracking and decarbonization process is paramount for identifying sources of issues and bottlenecks that requires immediate attention and resolution, as well as identifying opportunities for enhanced levels of streamlining, tracking, reporting, recognizing and incentivizing sustainability efforts and activities.

4. **Verifiability:** maintaining a solid governance, authentic and provenance rich environment over the data sets managed by sustainability blockchain applications and its surrounding ecosystem of enablers and partners, underscores the importance of operating on an open-source manner, or at least deploying measures that ease access by regulators and qualified assurance providers, to verify emissions and decarbonization tracking and reporting activities.
5. **Global South:** adopting blockchain enabled sustainability applications provides an ideal path to accelerate progress and growth for developing and emerging economies, especially most vulnerable populations that have missed on transformative technologies that arouse with the internet 1.0, 2.0 and 3.0, or been and continue to be affected significantly by physical infrastructure erosion, deforestation, loss of human potential and natural resources due to adverse events, including wars, climate change and increase in dumping practices.

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