Harnessing Blockchain Technology for the Delivery of Global Environmental Benefits

A STAP Advisory Document
December 2019

STAP
SCIENTIFIC AND TECHNICAL ADVISORY PANEL
An independent group of scientists that advises the Global Environment Facility

gef

UN environment programme

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ABOUT STAP:
The Scientific and Technical Advisory Panel (STAP) provides independent scientific and technical advice to the GEF on its strategies, programs and projects. https://stapgef.org

ABOUT GEF:
The Global Environment Facility (GEF) was established on the eve of the 1992 Rio Earth Summit to help tackle our planet's most pressing environmental problems. Since then, the GEF has provided close to $20.5 billion in grants and mobilized an additional $112 billion in co-financing for more than 4,800 projects in 170 countries. Through its Small Grants Programme, the GEF has provided support to nearly 24,000 civil society and community initiatives in 133 countries. http://www.thegef.org

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CONTENTS

1. BACKGROUND

The Scientific and Technical Advisory Panel (STAP) paper on novel entities[1] identified six novel entities and technologies of relevance to the Global Environment Facility (GEF): technology-critical elements, blockchain technology, next generation nanotechnology, gene editing/CRISPR, cellular agriculture, and new engineered bio-based materials.

This paper is the result of STAP's further work on one of those novel entities – blockchain technology – and is based on a review of the relevant literature and a STAP workshop that brought together experts on the environmental application of blockchain and members of the GEF Partnership. The paper explains what blockchain is, how blockchain could be used to deliver environmental benefits (particularly for the GEF), points out some of the challenges and barriers to using the technology, and concludes with recommendations to the GEF.

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2. WHAT IS BLOCKCHAIN TECHNOLOGY?

A ***blockchain*** is a type of database that is replicated over a peer-to-peer network and allows multiple users in the network to access, share, maintain and update the content of the database in real time, safely and securely, according to an agreed consensus mechanism and without the need for a trusted central authority.[2]

In a blockchain, data are grouped and organized into linked blocks; each block is secured using a cryptographic digital fingerprint called a "hash".[3] Each hash points to the next block, creating an unbroken chain of continuous data that can only be changed by modifying every block in the network, thus ensuring that the information within the network is secure and cannot be easily manipulated.[4] Blockchain uses an "append only" structure (i.e. data can only be added to the database; data cannot be deleted or altered on earlier blocks). This ensures that historical data and transactions are permanently stored and are immutable.[5]

Blockchain has several unique features that distinguish it from traditional database systems: more accurate record-keeping, greater transparency, increased trust, enhanced security, improved traceability, increased efficiency and speed, and lower-cost transactions.[6] Figure 1 shows how blockchain works.

Blockchain technology has been widely used as (i) a system for the secure, transparent and immutable distributed storage of digital identities and records; (ii) a basis for digitally representing and tracking real-world assets, such as commodities, natural resources, ecosystem services and waste (usually referred to as "digital tokens"[7]); and (iii) a platform for the formation and automated execution of digital relationships, transactions and markets (usually referred to as "smart contracts"[8]).

Blockchain allows for the secure management of a shared ledger, where transactions are verified and stored on a network without a governing central authority. Blockchains can come in different configurations, ranging from public, open-source networks to private blockchains that require explicit permissions to read or write. Computer science and advanced mathematics (in the form of cryptographic hash functions) are what make blockchains tick, not just enabling transactions but also protecting a blockchain's integrity and anonymity.

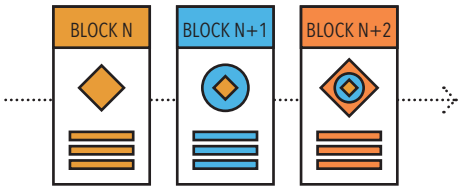
1

TRANSACTION Two parties exchange data; this could represent money, contracts, deeds, medical records, customer details, or any other asset that can be described in digital form.

2

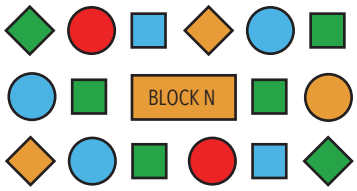
VERIFICATION Depending on the network's parameters, the transaction is either verified instantly or transcribed into a secured record and placed in a queue of pending transactions. In this case, nodes–the computers or servers in the network–determine if the transactions are valid based on a set of rules the network has agreed to.

3



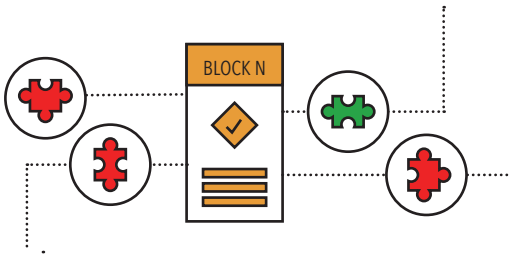
STRUCTURE Each block is identified by a hash, a 256-bit number, created using an algorithm agreed upon by the network. A block contains a header, a reference to the previous block's hash, and a group of transactions. The sequence of linked hashes creates a secure, interdependent chain.

4



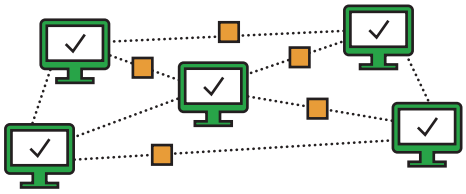
VALIDATION Blocks must first be validated to be added to the blockchain. The most accepted form of validation for open-source blockchains is proof of work–the solution to a mathematical puzzle derived from the block's header.

5



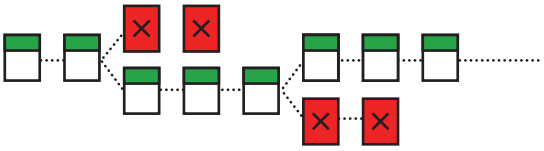
BLOCKCHAIN MINING Miners try to "solve" the block by making incremental changes to one variable until the solution satisfies a network-wide target. This is called "proof of work" because correct answers cannot be falsified; potential solutions must prove the appropriate level of computing power was drained in solving.

6



THE CHAIN When a block is validated, the miners that solved the puzzle are rewarded and the block is distributed through the network. Each node adds the block to the majority chain, the network's immutable and auditable blockchain.

7



BUILT-IN DEFENSE If a malicious miner tries to submit an altered block to the chain, the hash function of that block, and all following blocks, would change. The other nodes would detect these changes and reject the block from the majority chain, preventing corruption.

Figure 1: How blockchain works. (Source: Piscini et al. 2016[9])

3. WHAT CAN BLOCKCHAIN DO FOR THE ENVIRONMENT AND WHAT CAN IT NOT DO?

Blockchain cannot solve environmental problems on its own. Blockchain is an enabling technology that can help with the secure monitoring and tracking of environmental data and natural resources, thereby facilitating their effective management and enabling sustainable outcomes.

Environmental uses of blockchain typically require pairing it with a complementary technology, for example environmental sensors, satellite remote sensing, Internet of Things devices, artificial intelligence, biometrics, smart meters, QR Codes, or radio-frequency identification chips.

Environmental applications of blockchain:

- ***Improved environmental monitoring, reporting and verification.*** Blockchain can provide accurate record-keeping, as well as trust and transparency in recording and tracking environmental information and in monitoring compliance with multilateral environmental agreements,[10] such as the Paris Climate Agreement. For example:

  — The Yale OpenLab Open Climate project[11] aims to track the global carbon budget, monitor climate pledges and actions, and provide a platform for the international carbon market and the mobilization of climate finance.
  — The Regen Network blockchain[12] records ecosystem health and can be used, for example, to verify improvements or regeneration after an intervention.

- ***Sustainable resource management.*** Using blockchain to create a monetary value for natural resources and ecosystem services could encourage more sustainable consumption and production and create value in things that are currently wasted or undervalued.[13] For example:

  — The Plastic Bank[14] blockchain platform pays people for collecting and recycling plastic waste, thereby changing their perception of plastic waste from garbage to resource and simultaneously reducing ocean plastic pollution.
  — The GainForest blockchain[15] provides incentives for farmers to maintain forests at risk of deforestation by paying them for every period that the forest is preserved.

- ***Sustainable and transparent supply chains.*** Blockchain makes it is possible to track products from their origin through every stage and transaction to their final destination.[16] This can improve the transparency, credibility, efficiency and safety of commodity production and supply chains. Traceability will allow consumers to identify whether a product is from a sustainable source. A blockchain-based supply chain can also be used to reward sustainable behaviours directly.[17] For example:

  — Unilever is implementing a blockchain project to track and validate its tea supply chain. This will provide preferential pricing to farmers who use sustainable farming methods to produce more tea without increasing the land take.[18]

- ***Transformation of carbon and other environmental markets.*** Blockchain can help facilitate environmental markets (e.g. carbon emissions trading) by creating digital tokens to represent environmental improvement activities (e.g. tree planting, soil conservation actions, sustainable agriculture activities, renewable energy generation) that individuals or organizations can directly pay for to offset their environmental footprints. For example:

  — The CarbonX[19] and ClimateCoin[20] are blockchain networking platforms for individuals and companies to offset their

carbon emissions and to create demand for their low-emission products and services.

— The blockchain-based Nori Carbon Removal Marketplace[21] allows companies to offset their carbon emissions by paying farmers to restore soil health and pull carbon from the atmosphere.

— The OXÏ-ZEN Programme[22] makes it possible for carbon emitters to offset their emissions through payments to entities who mitigate carbon emissions by planting trees or conserving forests.

— The Earth Bank of Codes[23] collects and makes available data on biological assets. This allows scientists and innovators to tackle biopiracy and ensure a fair and equitable sharing of the economic benefits, in alignment with the objectives of the Nagoya Protocol.

- ***Sustainable urban and rural development.*** Blockchain can be used to:

  — Prepare a historical and immutable record of land and asset ownership.[24] Examples include the Bitland[25] and ChromaWay[26] blockchains, in use in Ghana and Sweden, respectively.

  — Improve the efficiency of waste management processes and incentivize recycling, for example Plastic Bank,[27] the End of Waste Foundation[28] and Recereum,[29] which are using blockchain to track waste, connect waste owners with entities that need the waste, and promote recycling and resource efficiency.

  — Support the implementation of decentralized systems for energy, water and other public utility management, which can help promote sustainable production and use; for example, FlexiDAO,[30] WePower[31] and WaterChain.[32]

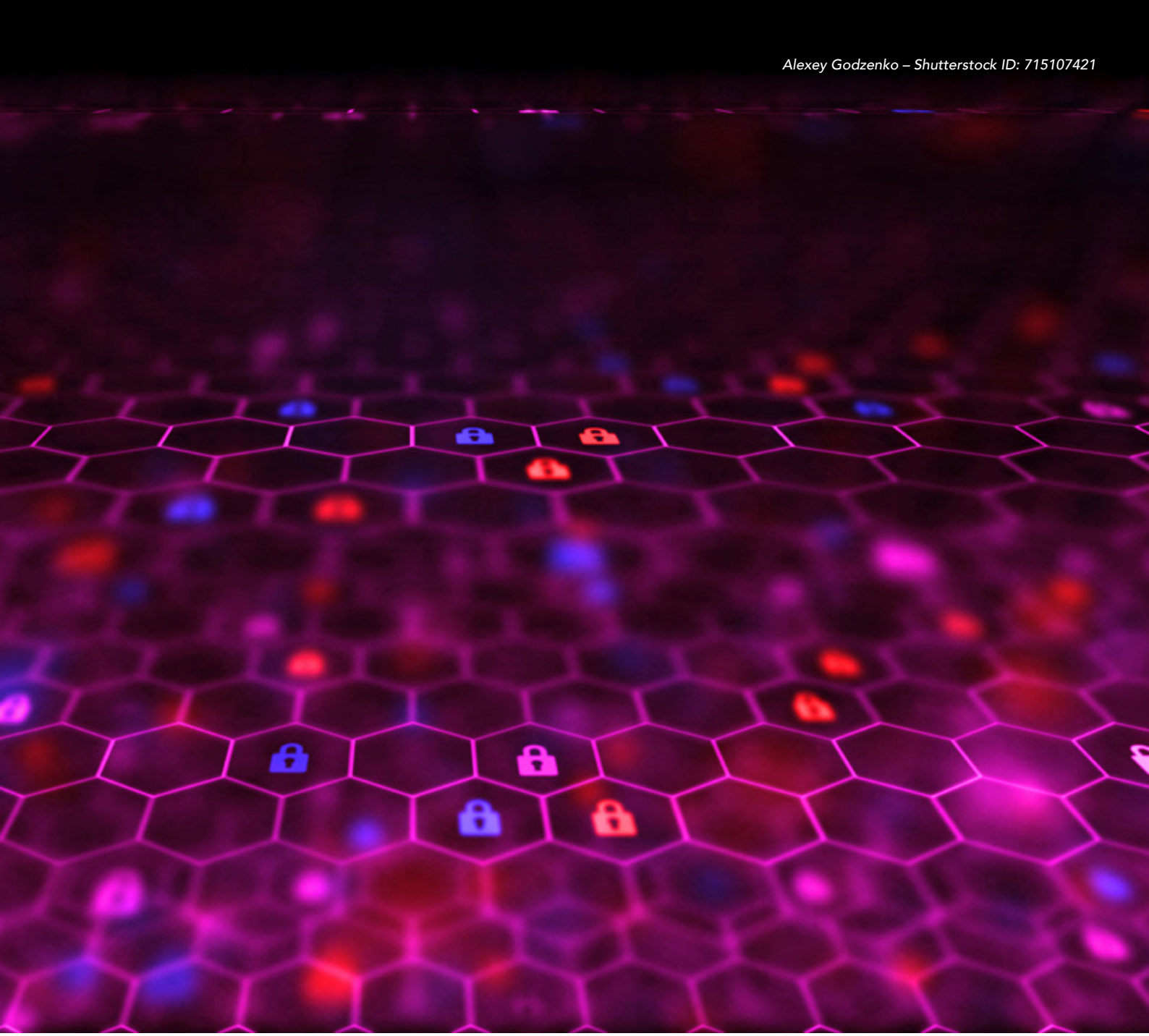
  — Implement peer-to-peer renewable energy trading systems, both in rural and urban areas,[33] which could increase the uptake of renewable energy; for example, SunContract[34] and the Exergy Brooklyn Microgrid.[35]

  — Support smart transportation and parking systems, as well as peer-to-peer electric vehicle charging stations and vehicle sharing;[36] for example, Omnitude uses GPS data, passenger information and journey tracking on a blockchain platform to deliver real-time transport solutions in Malta.[37]

  — Increase transparency and reduce bureaucracy in urban planning, city management and governance.[38]

- ***Innovative and sustainable environmental financing models.*** Blockchain can be used to create new financing structures and business models. It can be used for crowdfunding or impact investing[39] and to broaden opportunities for sustainable investment.[40] Its transparent and decentralized nature makes it easier to track investment and see whether the desired impacts are delivered. This may be particularly important in developing countries where regulatory standards for impact investment may have led to a perception that such investments are high risk. Blockchain may also help ensure that funding goes directly to the intended recipients. For example:

  — The IXO Foundation uses blockchain coupled with remote sensing and satellite imagery to monitor a tree-planting scheme and conservation efforts and to track associated impacts.[41] The blockchain platform also allows people to donate and receive real-time updates about the impacts of the scheme.



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4. WHAT OPPORTUNITIES DOES BLOCKCHAIN TECHNOLOGY OFFER THE GEF?

The environmental applications discussed in section 3 show that blockchain can be useful in delivering the GEF's objectives. To illustrate this, the objectives of the focal areas and Impact Programs of the GEF were mapped against a (non-exhaustive) list of existing and proposed blockchain uses. Figures 2a–2i present the outcome of this mapping exercise. The figures show that many proposed and existing blockchain applications are relevant to the objectives of the GEF, and the GEF can learn from them to improve its delivery of global environmental benefits. Annex 1 contains web links to the examples of blockchain applications in the figures.

GEF7 Objective
Address direct drivers to protect habitats and species
- Prevent, control and manage invasive alien species

Proposed Blockchain Use
Blockchain-based data platform for tracking species

GEF7 Objective
Mainstream biodiversity across sectors, landscapes and seascapes
- Mainstream in priority sectors
- Global Wildlife Program (preventing extinction)
- Natural capital assessment and accounting
- Sustainable use of plant and animal genetic resources

Existing or Proposed Blockchain Use

Mainstream biodiversity in agriculture
- Blockchain-supported Incentivization of farmers to protect habitats, e.g., Gainforest
- Blockchain-based recording of pesticide use in agriculture

Global Wildlife Program (preventing extinction)
- Blockchain-based tracking of health, geographical reach and movement of endangered species, e.g., Care for the Uncared blockchain
- Blockchain solution for protected and conserved areas, e.g., IUCN Green list standard token

Natural capital assessment and accounting
- Blockchain for investment in natural capital and payment for ecosystem services, e.g., the Natural Capital Coalition blockchain, Natural Asset Exchange blockchain platform, EarthToken, Veridium Labs natural capital marketplace

Sustainable use of plant and animal resource
- Plant and animal gene and lineage management, e.g., Amazon Bank of Codes, Earth Bank of Codes, WAGIF LineageCode

GEF7 Objective
Develop biodiversity policy and institutional framework
- Implement the Cartagena Protocol on biosafety and the Nagoya Protocol on Access and Benefit Sharing

Existing or Proposed Blockchain Use
Nagoya Protocol – Amazon Bank of Code and Earth Bank of Codes
Cartagena Protocol – blockchain-based tracking of the handling, transport and use of living modified organisms

Figure 2a: Blockchain applications relevant to the GEF's biodiversity focal area.

GEF7 Objective

Promote innovation and technology transfer in:

- Decentralized renewables with storage
- Electric mobility
- Energy efficiency

Existing or Proposed Blockchain Use

Decentralized renewable energy

- Blockchain-enabled peer-to-peer distribution and market for renewable energy though smart contracts, e.g., Exergy-Brooklyn Microgrid, PowerLedger, SunContract, WePower
- Tracking of renewable energy source and energy data management, e.g., Flexidao, WePower

Electric mobility

- Sharing of EV charging station across decentralized platform without middlemen, e.g., Elaadnl, Exergy EV charging, Matrix Charging System, PowerLedger, Share & Charge
- Blockchain-enabled peer-to-peer utilization of e-scooter, e.g., Xride

Energy efficiency and management

- Blockchain-supported smart home technology provide data and insight on energy consumption to help reduce consumption and carbon footprint, e.g., EnergiMine, Verv
- Blockchain-based smart energy management system, e.g., EnergiMine

Rewarding climate-conscious behavior

- for example, using less energy, taking public transport, buyi ng energy efficient appliance etc., e.g., Energi Tokens

Measuring and rewarding renewable energy generation and credit

- for example, Clearway Energy Group & PowerLedger, SolarCoin, South Pole/IXO/Gold Standard MRV Blockchain

GEF7 Objective

Foster enabling conditions for mainstreaming mitigation

- Capacity-building Initiative for Transparency
- Enabling activities, e.g., national communications and biennial report preparation

Existing or Proposed Blockchain Use

Climate accounting system

- Yale OpenLab Climate Project

Ledger for collection of MRV data

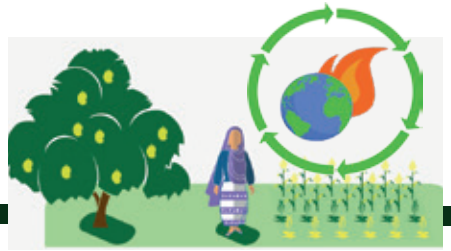
- Climate Ledger Initiative

Measuring and rewarding renewable energy generation and credit

- for example, Clearway Energy Group & PowerLedger, SolarCoin, South Pole/IXO/Gold Standard MRV Blockchain

Figure 2b: Blockchain applications relevant to the GEF's climate change mitigation focal area.

Note: EV = electric vehicle; MRV = Monitoring Reporting and Verification.



LDCF and SCCF Strategic Goal

Strengthen resilience and reduce vulnerability to the adverse impacts of climate change in developing countries and support their efforts to enhance adaptive capacity

Existing or Proposed Blockchain Use

Improving resilience in agriculture

- Blockchain-supported crop insurance, e.g., Aon/Etherisc/ Oxfam Crop Insurance, Blockchain Climate Risk Crop Insurance, WorldCover

Strengthening resilience of the most vulnerable

- Blockchain-based identification and financial access for the unbanked and vulnerable, e.g., WFP Building Blocks Platform
- Blockchain-supported platform for access to climate finance for local people, e.g., HARA Token

Resilient infrastructure

- Decentralized mini-grids with blockchain load management system to improve resilience and blockchain-enabled microgrids for responding to power failures, e.g., L03 Energy

Early warning and disaster resilience

- Blockchain-backed decentralized weather sensors for monitoring, forecasts and alerts, e.g., WeatherBlock
- Decentralized disaster insurance platform, e.g., Etherisc

Adaptation metrics and finance

- Blockchain-enabled verification of ecological outcomes, such as improvement in mangroves or land, or success of climate-smart or nature-based agricultural solutions, e.g., Regen Network
- Vulnerability reduction credits for assessing success, attributing credit and mobilizing finance for adaptation effort, e.g., Adaptation Ledger.
- Blockchain-enabled platforms to manage investment that can be used towards climate change adaptation interventions, e.g., Crowdwiz's Wizfund, EthicHub
- Smart tokens for philanthropic cash transfer and support to disaster victims, e.g., Givetrack

Figure 2c: Blockchain applications relevant to strategic goal of the GEF's climate change adaptation focal area.

Note: LDCF = Least Developed Countries Fund; SCCF = Special Climate Change Fund.

GEF7 Objective
Support on-the-ground implementation of Sustainable Land Management to achieve Land Degradation Neutrality

Existing or Proposed Blockchain Use

- Marketplace for incentivizing and rewarding farmers for preserving soil carbon, e.g., Nori Carbon Removal Marketplace
- Blockchain-enabled verification of ecological outcomes, such as decreased land degradation, e.g., Regen Network
- Incentivizing and supporting sustainable agriculture by smallholder farmers, e.g., AgriLedger, AgUnity, GainForest, IBM Africa & Hello Tractor, RainTrust Agro-Blockchain, Shamba Records, Unilever pilot for tea supply chain
- Blockchain-powered data recording of soil conditions and farming practice to inform agriculture financing, increased production, and sustainable farm management, e.g., HARA Token
- Blockchain-based sustainable forest management, e.g., BVRio Responsible Timber Exchange Platform, ChainWood, Hangzhou Yi Shu Blockchain Technology
- Blockchain-supported sustainable mining practice by tracking the source of minerals, e.g., IBM TrustChain, Ford's cobalt pilot project
- Blockchain-supported agri-food supply chain tracking and traceability, e.g., AgriLedger, Ambrosus Blockchain, Bext360 Blockchain Supply Chain, OriginTrail, Provenance Blockchain Poultry Supply Chain, Ripe.io Blockchain of Food, Skuchain Supply Chain, TE-FOOD FoodChain, Unilever pilot for tea supply chain

GEF7 Objective
Create an enabling environment to support voluntary Land Degradation Neutrality target implementation

Existing or Proposed Blockchain Use

- Blockchain-based land tenure registry and administration, e.g., BenBen, BigchainDB, Bitfury,Bitland, ChromaWay, ConsenSys, Epigraph
- Incentivizing and supporting sustainable agriculture by smallholder farmers, e.g., AgriLedger, AgUnity, GainForest, IBM Africa & Hello Tractor, RainTrust Agro-Blockchain, Shamba Records, Unilever pilot for tea supply chain

Figure 2d: Blockchain applications relevant to the GEF's land degradation focal area.

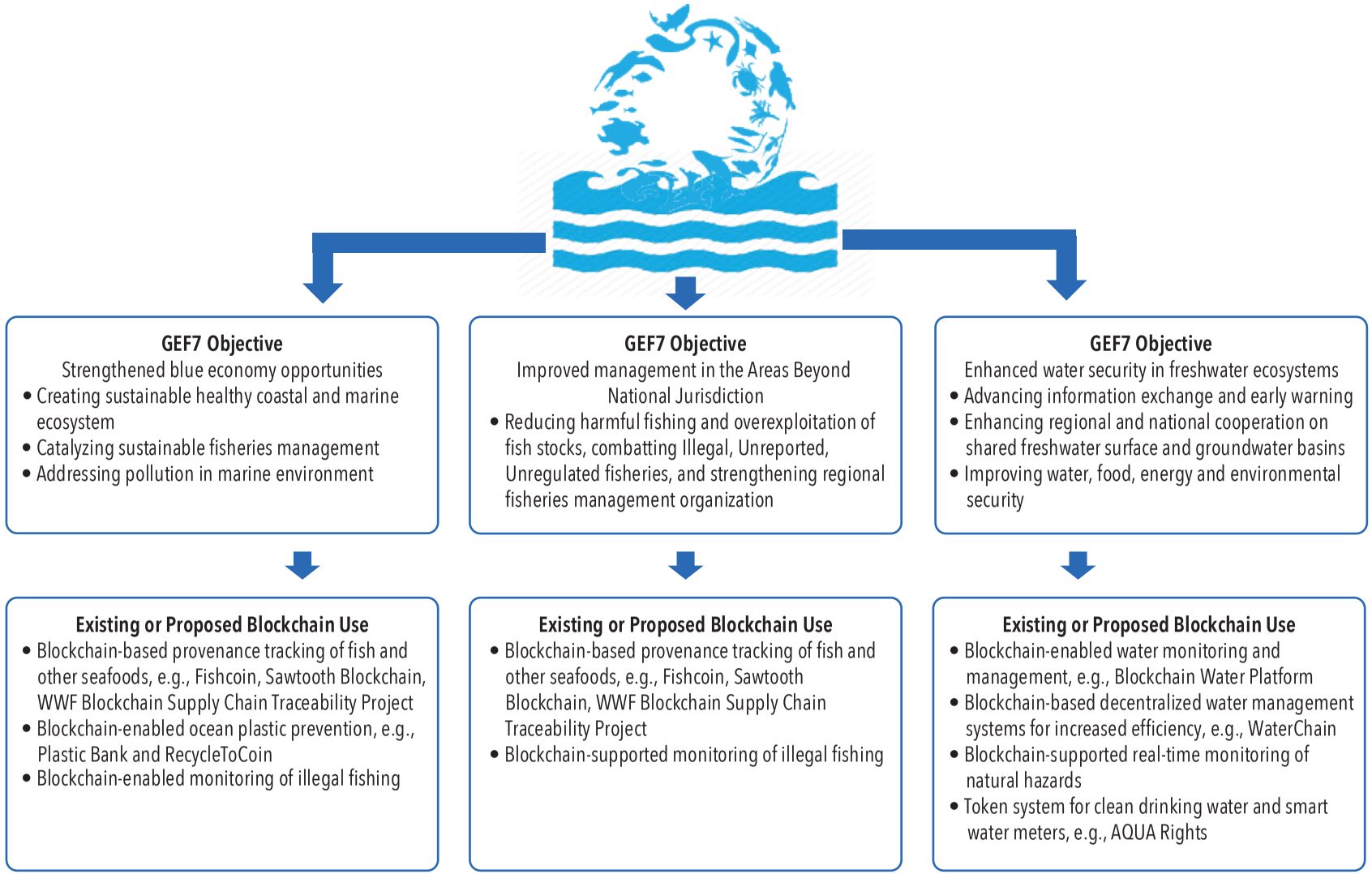


Figure 2e: Blockchain applications relevant to the GEF's international waters focal area.

GEF7 Objective
Eliminate/restrict/control emissions of Stockholm chemicals; eliminate emissions and release of mercury in activities and processes; encourage public-private partnership; support SAICM objectives

Programs

- Eliminate or reduce **industrial chemicals** under Stockholm, Minamata, SAICM and Montreal Protocol
- Address and reduce use of Stockholm and Minamata-related **agricultural chemicals**
- Sound management of chemicals and waste in **Least Developed Countries** and **Small Island Developing States**
- Support conventions-related **enabling activities**

Existing or Proposed Blockchain Use

- Blockchain-based traceability and tracking in chemical supply chains, e.g., Chemchain
- Blockchain-enabled monitoring of chemical use in agriculture
- Blockchain-facilitated regulatory enforcement and customs control, e.g., CADENA blockchain, Tradelens
- Waste management system supported by blockchain, e.g., 4New Waste-to-Energy Blockchain, Agora Tech Lab, End of Waste Foundation, Plastic Bank, Recereum, RecycleToCoin, Swachhcoin
- Tracking of waste, in particular e-waste and its documentation up to final destination, e.g., WasteLedger
- Blockchain-enabled circular and sharing economy, e.g., Bundles pay-per-use washing machine, Circularise, Circulor Oracle Blockchain for Supply Chain Tracking, La'Zooz, Plastic Bank, Provenance, TradeLens
- Blockchain-enabled tracking of mineral resources like gold, cobalt, diamonds, e.g., Circulor Oracle Blockchain for Supply Chain Tracking, Emergent Technology Responsible Gold, Forcefield Metals Trade Blockchain Consortium, EverLedger, Tracr blockchain

Figure 2f: Blockchain applications relevant to the GEF's chemicals and waste focal area.

Note: SAICM = Strategic Approach to International Chemicals Management.

GEF7 Objective
Create efficient and effective food value chains for multiple benefits

Existing or Proposed Blockchain Use

- Blockchain-based incentivizing and support of sustainable agriculture by smallholder farmers, e.g., AgriLedger, AgUnity, GainForest, Hello Tractor, RainTrust Agro-Blockchain, Regen Network, Shamba Records, Unilever pilot for tea supply chain
- Blockchain-based recording of pesticide use in agriculture
- Blockchain-based provenance tracking of food value chain, e.g., BeefChain, BeefLedger, WWF Blockchain Supply Chain Traceability Project for Tuna fish
- Marketplace for incentivizing and rewarding farmers for preserving soil carbon, e.g., Nori Carbon Removal Marketplace

GEF7 Objective
Remove deforestation from supply chains

Existing or Proposed Blockchain Use

- Blockchain-supported agri-food supply chain tracking and traceability, e.g., AgriLedger, Ambrosus Blockchain, Bext360 Blockchain Supply Chain, OriginTrail, Provenance Blockchain Poultry Supply Chain, Ripe.io Blockchain of Food, Skuchain Supply Chain, TE-FOOD Blockchain, Unilever pilot for tea supply chain
- Blockchain-based sustainable forest management, e.g., BVRio Responsible Timber Exchange Platform, ChainWood, Hangzhou Yi Shu Blockchain Technology

GEF7 Objective
Expand restoration of degraded lands

Existing or Proposed Blockchain Use

- Marketplace for incentivizing and rewarding farmers for preserving soil carbon, e.g., Nori Carbon Removal Marketplace
- Blockchain-enabled verification of ecological outcomes, such as decreased land degradation, e.g., Regen Network
- Incentivizing and supporting sustainable agriculture by smallholder farmers, e.g., AgriLedger, AgUnity, GainForest, Hello Tractor, RainTrust Agro-Blockchain, Regen Network, Shamba Records, Unilever pilot for tea supply chain
- Blockchain-based data recording of soil conditions and farming practice to inform agriculture financing and sustainable farm management

Figure 2g: Blockchain applications relevant to the GEF's Food Systems, Land Use, and Restoration Impact Program.

Program Components

Promoting innovative business models for integrated solutions and investments at city-level

Strengthening the Global Platform for Sustainable Cities for knowledge exchange and learning

GEF Sustainable Cities Investment Categories

Supporting evidence-based spatial planning – national, regional and local

Existing or Proposed Blockchain Use

- Blockchain-based land tenure registry and administration, e.g., BenBen, BigchainDB, Bitfury, Bitland, ChromaWay, ConsenSys, Epigraph
- Blockchain-based public, corporate, civil and asset registry, e.g., Bitfury, Ubitquity

Decarbonizing urbanization with infrastructure integration at national, regional, and local scales

Existing or Proposed Blockchain Use

- Blockchain-supported intelligent transport and logistic systems, e.g., Blockchain in Transport Alliance, MOBI blockchain, NetObjex, Omnitude & Maltese Government, Volt P2P Delivery Platform
- Blockchain-enabled peer-to-peer distribution and market for renewable energy though smart contracts, e.g., Exergy Brooklyn Microgrid, Power Ledger, SunContract, WePower
- Tracking of renewable energy source and energy data management, e.g., FlexiDao, WePower
- Smart EV charging systems, e.g., ElaadNL, Exergy EV charging, Matrix Charging System, PowerLedger, Share & Charge
- Blockchain-enabled car sharing e.g., La'Zooz.
- Blockchain-support household waste to energy, e.g., 4New Waste-to-Energy

Building deep resilience with smart systems and slum solutions

Existing or Proposed Blockchain Use

- Blockchain-enabled community participation which can enhance urban planning and improve decision making, e.g., Polys Voting Blockchain
- Blockchain-based land tenure registry and administration, e.g., BenBen, BigchainDB, Bitfury, Bitland, ChromaWay, ConsenSys, Epigraph
- Blockchain-based smart grid and energy load management system
- Waste management system supported by blockchain, e.g., 4New Waste-to-Energy Blockchain, Agora Tech Lab, End of Waste Foundation, Plastic Bank, Recereum, RecycleToCoin, Swachhcoin
- Blockchain-enabled circular and sharing economy, e.g., Bundles pay-per-use washing machine, Circularise, Circulor Oracle Blockchain for Supply Chain Tracking, La'Zooz, Plastic Bank, Provenance, TradeLens

Cascading finance solutions for urban sustainability

Existing or Proposed Blockchain Use

- Blockchain-enabled finance platforms for raising funds and investments for environmental sustainability, e.g., Crowdwiz's WizFund, Sun Exchange
- Peer-to-peer personal or corporate carbon trading, e.g., CarbonX, ClimateCoin, Earth Dollar

Figure 2h: Blockchain applications relevant to the GEF's Sustainable Cities Impact Program

Note: EV = electric vehicle.

Focus on globally important forests

Amazon Forest	Congo Basin Forest	Dryland Forests

Examples of Planned Interventions

- Creating a better enabling environment for forest governance
- Supporting rational land-use planning across mixed-use landscapes
- Strengthening protected areas
- Clarifying land tenure and other relevant policies
- Supporting the management of commercial and subsistence agriculture lands to reduce pressure on adjoining forests
- Employing financial mechanisms and incentives for sustainable forest utilization, such as markets, REDD+ and other payments for ecosystem services

Existing or Proposed Blockchain Use

- Blockchain-enabled market-based forest conservation and protection, e.g., Ecosphere+ REDD+ Unchained, CarbonCoin, OXÏ-ZEN Programme, REDD-Chain, Travel4Green project
- Blockchain-enabled verification of ecological outcomes, such as improved forest cover and decreased land degradation, e.g., Regen Network.
- Blockchain-supported sustainable mining practice by tracking the source minerals, e.g., EverLedger, Emergent Technology Responsible Gold, Forcefield Metals Trade Blockchain Consortium, Ford's cobalt pilot project, IBM TrustChain, Tracr Blockchain,
- Blockchain-based sustainable forest management, e.g., BVRio Responsible Timber Exchange Platform, ChainWood, Hangzhou Yi Shu Blockchain Technology
- Blockchain-based incentivizing and support of sustainable agriculture by smallholder farmers, e.g., AgriLedger, AgUnity, GainForest, Hello Tractor, RainTrust Agro-Blockchain, Regen Network, Shamba Records, Unilever pilot for tea supply chain
- Blockchain-based provenance tracking of food value chain, e.g., BeefLedger and BeefChain.
- Marketplace for incentivizing and rewarding farmers for preserving soil carbon, e.g., Nori Carbon Removal Marketplace
- Blockchain-supported agri-food supply chain tracking and traceability, e.g., AgriLedger, Ambrosus Blockchain, Bext360 Blockchain Supply Chain, OriginTrail, Provenance Blockchain Poultry Supply Chain, Ripe.io Blockchain of Food, Skuchain Supply Chain, TE-FOOD Blockchain, Unilever pilot for tea supply chain
- Blockchain-based land tenure registry and administration, e.g., BenBen, BigchainDB, Bitfury, Bitland, ChromaWay, ConsenSys, Epigraph

Figure 2i: Blockchain applications relevant to the GEF's Sustainable Forest Management Impact Program.

Note: REDD+ = reduce emissions from deforestation and forest degradation in developing countries.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5. WHAT ARE SOME OF THE CHALLENGES AND BARRIERS TO BLOCKCHAIN?

In considering blockchain, the GEF should be aware of some of the challenges and barriers to its use. These include:

- ***Carbon and material footprint.*** The first blockchain systems, including Bitcoin, have large computational and energy requirements owing to the algorithm used for consensus building.[42] Servers to power blockchain also use a range of metals. Newer blockchain systems that use less energy are being developed, but the overall energy and material use should be considered when deciding whether to use blockchain.

- ***Data collection and security.*** Ideally, the collection of blockchain data should not involve human data entry, because this is more prone to error and manipulation. Blockchain therefore needs to be paired with automated, secure and accurate data-collection systems. The need for these complementary technologies makes using blockchain more challenging, especially in many developing countries, where access to these technologies may be limited.

- ***Scalability***. Many blockchain applications have not been scaled beyond context-specific, proof-of-concept pilot applications, largely because of the need for high computational power and the limited speed of transactions. These issues would need to be addressed if blockchain were to be used on large-scale environmental problems that required several actors within the blockchain.

- ***Digital access and literacy in developing countries.*** The lack of digital literacy and Internet access may make it difficult for some rural communities to participate in blockchain-enabled solutions, for example in supply chains involving smallholder farmers or natural resource management involving local participation. Investment in infrastructure or research to create low-cost alternatives suitable for developing countries may be required.[43]

Other issues that may impede the adoption of blockchain are the lack of an agreed governance structure and the absence of standards and protocols.

6. STAP'S ADVICE AND RECOMMENDATIONS

STAP recommends that the GEF consider how blockchain can improve its delivery of global environmental benefits. In particular, STAP recommends the following:

- **Consider blockchain pilot projects.**
  Some areas seem particularly ripe for the GEF to incorporate blockchain. For example:

  — Tracking and verifying sustainable charcoal production (Land Degradation focal area; Sustainable Forest Management Impact Program)
  — Reducing deforestation in agricultural systems by improving transparency in supply chains and incentivizing producers to implement more sustainable environmental practices (Food Systems, Land Use, and Restoration Impact Program; Land Degradation and Biodiversity focal areas)
  — Improving the security and accuracy of land tenure systems (Land Degradation focal area; Sustainable Forest Management; Food Systems, Land Use, and Restoration Impact Program; Sustainable Cities Impact Program)
  — Improving water and energy resource management (Climate Change and International Waters focal areas; Sustainable Cities Impact Program)
  — Improving energy access through decentralized renewable energy sources paired with microgrids, which can enable peer-to-peer markets and community trading (Climate Change focal area; Sustainable Cities Impact Program)
  — Improving the traceability of energy sources, which can allow differentiation between renewables and fossil fuels (Climate Change focal area)
  — Decarbonizing transportation systems (Climate Change focal area; Sustainable Cities Impact Program)
  — Improving the traceability and tracking of chemical supply chains (Chemicals and Waste focal area)
  — Improving waste management and the circular economy (Chemicals and Waste focal area; Sustainable Cities Impact Program)

- **Assess the value proposition of blockchain to be sure it would add value before adoption.**
  Blockchain can be used in many ways but may not always be necessary or add enough value to justify its use. Investment in blockchain, as an early-stage technology, will involve some degree of risk. The GEF should therefore assess blockchain's value proposition in the context of a specific investment before proceeding. Using blockchain should be balanced against its potential drawbacks, including its cost and energy requirements, as well as whether it is appropriate to achieve the intended objectives. A reasoned and structured approach is needed to guide blockchain adoption in specific situations.

  Possible assessment questions may include:

  — Can this project be implemented without blockchain?
  — Is blockchain the best available solution to the problem? Are there alternatives? How is blockchain better than the best status quo alternative? By what measure?
  — Are decentralization, transparency and traceability essential to achieve the project's goals?
  — Does using blockchain increase the capacity of the project to deliver global environmental benefits?
  — Will the blockchain solution require complementary technologies, and are these in place?
  — Does the community have the digital readiness and financial literacy to engage with a blockchain application, or is capacity-building a prerequisite for implementation?
  — If capacity-building is needed, can it be included in the project? If not, how would the capacity building be achieved?

- What are the possible unintended consequences of adopting blockchain, and how will they be managed?
- What are the environmental impacts associated with the blockchain solution? Are they justifiable? What is the net environmental benefit?
- How would the blockchain application manage data privacy and data security?
- Is the blockchain solution scalable, and are the outcomes transformational?
- Does the project have the right ecosystem of stakeholders?

- **Explore possible blockchain benefits to existing GEF programmes and processes.**
  For example:

  - Consider existing internal GEF processes or programmes to see if blockchain could improve record-keeping, transparency, trust, security, efficiency or cost, without unintended negative impacts.
  - Consider whether and, if so, how blockchain technology could be used in knowledge management and in monitoring and evaluation.
  - Consider whether blockchain could be used to monitor the long-term durability of GEF projects.

- **Engage with existing initiatives that are developing environmental applications of blockchain.**
  The GEF can leverage initiatives and programmes already working on blockchain applications in relation to environmental challenges to create blockchain solutions for GEF-specific environmental challenges or to access technical assistance for potential GEF projects that are considering blockchain. Examples of these initiatives include:

  - Climate Chain Coalition[44] – A collaboration of diverse stakeholders that aims to use blockchain and other digital technologies to mobilize climate finance and improve measuring, reporting and verification of climate actions.
  - Yale OpenLab[45] – A collaboration that aims to create open source and disruptive projects to address planetary challenges.
  - BitHub Africa[46] – A blockchain accelerator organization focused on financial and energy access in Africa.
  - GIZ Blockchain Lab[47] – A blockchain lab with a focus on using the technology to achieve the 2030 Agenda for Sustainable Development.
  - The World Bank Group's Technology and Innovation Lab[48] – A lab that focuses on using technologies including blockchain to address issues like land administration, supply chain management, health and carbon market trading to reduce poverty.

ANNEX 1. WEB LINKS TO THE EXAMPLES OF BLOCKCHAIN APPLICATIONS PRESENTED IN FIGURES 2A–2I (IN ALPHABETICAL ORDER)

4New Waste-to-Energy Blockchain: https://4new.io

Adaptation Ledger: https://www.adaptationledger.com

Agora Tech Lab: https://www.agoratechlab.com

AgriLedger: http://www.agriledger.io

AgUnity: https://www.agunity.com

Amazon Bank of Codes: https://www.earthbankofcodes.org/

Ambrosus Blockchain: https://ambrosus.com

Aon/Etherisc/Oxfam Crop Insurance: https://etherisc.com

AQUA Rights: https://aquarights.com

BeefChain: https://beefchain.com

BeefLedger: https://beefledger.io

BenBen: http://www.benben.com.gh

Bext360 Blockchain Supply Chain: https://www.bext360.com

BigchainDB: https://www.bigchaindb.com

Bitfury: https://bitfury.com

Bitland: http://landing.bitland.world

Blockchain Climate Risk Crop Insurance: https://www.climatefinancelab.org/project/climate-risk-crop-insurance

Blockchain in Transport Alliance: https://www.bita.studio

Blockchain Water Platform: https://www.blockchainwater.ai

Bundles pay-per-use: https://www.circle-economy.com/case/bundles/#.XdmlTOhKiUk

BVRio Responsible Timber Exchange Platform: https://www.bvrio.com

CADENA blockchain: https://mag.wcoomd.org/magazine/wco-news-87/cadena-a-blockchain-enabled-solution-for-the-implementation-of-mutual-recognition-arrangements-agreements

CarbonCoin: https://carboncoin.cc

CarbonX: https://www.carbonx.ca

Care for the Uncared: https://www.investereum.com/2019/02/09/the-happy-blockchain-animals

ChainWood: https://www.chainwood.eu

Chemchain: https://www.chemcha.in

ChromaWay: https://chromaway.com

Circularise: https://www.circularise.com

Circulor Oracle Blockchain: https://www.circulor.com

Clearway Energy Group & Power Ledger: https://www.powerledger.io/project/clearway-energy-group-united-states

ClimateCoin: https://climatetrade.com

Climate Ledger Initiative: https://www.climateledger.org

ConsenSys: https://consensys.net/blockchain-use-cases/real-estate

CrowdWiz WizFund: https://crowdwiz.io

Earth Bank of Codes: https://www.earthbankofcodes.org

Earth Dollar: https://earthdollar.org

Earth Token: https://earth-token.com

Ecosphere+ REDD+ Unchained: https://ecosphere.plus/2018/11/05/redd-unchained-blockchain-and-climate-change-mitigation-2

ElaadNL: https://www.elaad.nl

Emergent Technology Responsible Gold: https://www.emergenttechnology.com/companies/responsible-gold

End of Waste Foundation: https://endofwaste.com

EnergiMine: https://energimine.com

Energi Tokens: https://www.energi.world

Epigraph: http://epigraph.io

Etherisc: https://etherisc.com

EthicHub: https://ethichub.com

EverLedger: https://www.everledger.io

Exergy: https://exergy.energy

Exergy EV charging: https://lo3energy.com

Fishcoin: https://fishcoin.co

FlexiDAO: https://www.flexidao.com

Forcefield Metals Trade Blockchain: https://www.ledgerinsights.com/commodities-blockchain-consortium-forcefield-accenture-ing-anb-amro-anglo-american

Ford's cobalt pilot project: https://www.supplychaindive.com/news/Ford-IBM-team-up-track-minerals-blockchain/546301

GainForest: https://www.gainforest.app

Givetrack: https://www.givetrack.org

Hangzhou Yi Shu Blockchain Technology: https://cointelegraph.com/news/chinese-county-establishes-blockchain-company-to-develop-forestry-industry

HARA Token: https://haratoken.io

IBM Africa & Hello Tractor: https://www.hellotractor.com/ibm

IBM TrustChain: https://www.trustchainjewelry.com

IUCN Green List standard token: https://gls.porini.foundation

La'Zooz: http://lazooz.org

LO3 Energy: https://lo3energy.com

Matrix Charging system: https://www.ico.li/blockchain-and-e-mobility

MOBI: https://dlt.mobi

Natural Asset Exchange: https://www.naturalasset.exchange

Natural Capital Coalition: https://naturalcapitalcoalition.org/the-natural-capital-blockchain-revolution

NetObjex: https://www.netobjex.com/use-cases

Nori Carbon Removal Marketplace: https://nori.com

Omnitude & Maltese Government: https://omnitude.tech/omnitude-the-maltese-govt

OriginTrail: https://origintrail.io

OXÏ-ZEN Programme: https://www.oxi-zen.io

Plastic Bank: https://plasticbank.com

Polys voting blockchain: https://polys.me

Power Ledger: https://www.powerledger.io

Provenance: https://www.provenance.org

Provenance Blockchain Poultry Supply Chain: https://www.provenance.org/case-studies/grass-roots

RainTrust Agro-Blockchain: https://raintrust.io

Recereum: https://recereum.com

RecycleToCoin: https://iywto.com/things/recycle-cans/recycle-to-coin

REDD-Chain: http://cleantech21.org/fileadmin/content/NBE/C21_H4C_REDD-Chain_Sum082018_v04.pdf

Regen Network: https://www.regen.network

Ripe.io Blockchain of Food: https://www.ripe.io

Sawtooth Blockchain: https://sawtooth.hyperledger.org/examples/seafood.html

Shamba Records: https://shambarecords.co.ke

Share & Charge: https://shareandcharge.com

Skuchain Supply Chain: https://www.skuchain.com

SolarCoin: https://solarcoin.org

South Pole/IXO/Gold Standard MRV Blockchain: https://www.goldstandard.org/tags/blockchain

SunContract: https://suncontract.org

Sun Exchange: https://thesunexchange.com

Swachhcoin: http://www.swachhcoin.com

TE-FOOD FoodChain: https://tefoodint.com

Tracr blockchain: https://www.tracr.com

TradeLens: https://www.tradelens.com

Travel4Green: http://t4gpng.org

Ubitquity: https://www.ubitquity.io

Unilever pilot for tea supply: https://www.greenbiz.com/article/unilever-teams-big-banks-blockchain-supply-chain

Veridium: https://www.veridium.io

Verv: https://verv.energy

Volt P2P Delivery Platform: https://ico-tokensale.com/volt

WAGIF LineageCode: https://www.lineagecode.com

WasteLedger: https://www.f6s.com/wasteledger

WaterChain: https://www.waterchain.io

WeatherBlock: http://www.weatherblock.org

WePower: https://wepower.network

WFP Building Blocks: https://innovation.wfp.org/project/building-blocks

WorldCover: https://www.worldcovr.com

WWF Blockchain Supply Chain Traceability Project: https://www.wwf.org.nz/what_we_do/marine/blockchain_tuna_project

Xride: https://laboratories.telekom.com/blockchain-scooter

Yale OpenLab Open Climate: https://openlab.yale.edu/open-climate

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