Harnessing Blockchain Technology for the Delivery of Global Environmental Benefits

A STAP Advisory Document
December 2019
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1. BACKGROUND


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.
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"³); 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.

**Figure 1: How blockchain works. (Source: Piscini et al. 2016)**

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)
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, such as the Paris Climate Agreement. For example:
  - The Yale OpenLab Open Climate project 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 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. For example:
  - The Plastic Bank 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 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 possible to track products from their origin through every stage and transaction to their final destination. 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. 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.

- **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 and ClimateCoin 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\textsuperscript{21} allows companies to offset their carbon emissions by paying farmers to restore soil health and pull carbon from the atmosphere.

— The OXž-ZEN Programme\textsuperscript{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\textsuperscript{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.\textsuperscript{24} Examples include the Bitland\textsuperscript{25} and ChromaWay\textsuperscript{26} blockchains, in use in Ghana and Sweden, respectively.

  — Improve the efficiency of waste management processes and incentivize recycling, for example Plastic Bank,\textsuperscript{27} the End of Waste Foundation\textsuperscript{28} and Recereum,\textsuperscript{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,\textsuperscript{30} WePower\textsuperscript{31} and WaterChain.\textsuperscript{32}

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

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

  — Increase transparency and reduce bureaucracy in urban planning, city management and governance.\textsuperscript{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\textsuperscript{39} and to broaden opportunities for sustainable investment.\textsuperscript{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.\textsuperscript{41} The blockchain platform also allows people to donate and receive real-time updates about the impacts of the scheme.
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.
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

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
Decentralized renewable energy
- Blockchain-enabled peer-to-peer distribution and market for renewable energy through 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, buying 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

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.

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**Existing or Proposed Blockchain Use**

### 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

### 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., LO3 Energy

### 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., Crowdziz’s Wizfund, EthicHub
- Smart tokens for philanthropic cash transfer and support to disaster victims, e.g., Givetrack

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**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.*
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**
Strengthened blue economy opportunities
- Creating sustainable healthy coastal and marine ecosystem
- Catalyzing sustainable fisheries management
- Addressing pollution in marine environment

**GEF7 Objective**
Improved management in the Areas Beyond National Jurisdiction
- Reducing harmful fishing and overexploitation of fish stocks, combatting Illegal, Unreported, Unregulated fisheries, and strengthening regional fisheries management organization

**Existing or Proposed Blockchain Use**
- Blockchain-based provenance tracking of fish and other seafoods, e.g., Fishcoin, Sawtooth Blockchain, WWF Blockchain Supply Chain Traceability Project
- Blockchain-enabled ocean plastic prevention, e.g., Plastic Bank and RecycleToCoin
- Blockchain-enabled monitoring of illegal fishing

**Existing or Proposed Blockchain Use**
- Blockchain-based provenance tracking of fish and other seafoods, e.g., Fishcoin, Sawtooth Blockchain, WWF Blockchain Supply Chain Traceability Project
- Blockchain-supported monitoring of illegal fishing

**Existing or Proposed Blockchain Use**
- Blockchain-enabled water monitoring and management, e.g., Blockchain Water Platform
- Blockchain-based decentralized water management systems for increased efficiency, e.g., WaterChain
- Blockchain-supported real-time monitoring of natural hazards
- Token system for clean drinking water and smart water meters, e.g., AQUA Rights

**GEF7 Objective**
Enhanced water security in freshwater ecosystems
- Advancing information exchange and early warning
- Enhancing regional and national cooperation on shared freshwater surface and groundwater basins
- Improving water, food, energy and environmental security
**Figure 2f: Blockchain applications relevant to the GEF’s chemicals and waste focal area.**

Note: SAICM = Strategic Approach to International Chemicals Management.
Figure 2g: Blockchain applications relevant to the GEF’s Food Systems, Land Use, and Restoration Impact Program.

**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, Best360 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 2h: Blockchain applications relevant to the GEF’s Sustainable Cities Impact Program

Note: EV = electric vehicle.
Examples of Planned Interventions

- 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-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
- Blockchain-enabled market-based forest conservation and protection, e.g., Ecosphere+ REDD+ Unchained, CarbonCoin, OXi-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,
- 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

Focus on globally important forests
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. 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.

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\textsuperscript{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\textsuperscript{45} – A collaboration that aims to create open source and disruptive projects to address planetary challenges.
  — BitHub Africa\textsuperscript{46} – A blockchain accelerator organization focused on financial and energy access in Africa.
  — GIZ Blockchain Lab\textsuperscript{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\textsuperscript{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
- **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
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

Garrick Hileman and Michael Rauchs, Global Blockchain Benchmarking Study (Cambridge, United Kingdom, Cambridge Centre for Alternative Finance, 2017); Deloitte, “Blockchain: A technical primer”, Deloitte Insights, 6 February 2018; Miram Denis Le Sève, Nathaniel Mason and Darius Nassiry, “Delivering blockchain’s potential for environmental sustainability”, Overseas Development Institute, October 2018.

A “hash” is a unique string of letters and numbers created from text using a mathematical formula.


Blockchains are said to be almost immutable because of the huge effort that is needed to successfully change an entry in the database. To successfully change an entry, one would need to change all the historical data on every single node.


Digital tokens (also referred to as “crypto-tokens”) are used to represent a particular fungible and tradable asset or utility. Anyone in possession of the digital token, therefore, has the right to use the token and trade it digitally. Smart contracts are digital protocols that help facilitate, authenticate and administer the negotiation and implementation of a contract as agreed by all parties, but without third parties.

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