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INVESTING IN OUR PLANET

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HARNESSING BLOCKCHAIN TECHNOLOGY FOR THE DELIVERY OF GLOBAL ENVIRONMENTAL BENEFITS

Harnessing Blockchain Technology for the Delivery of Global Environmental Benefits

A STAP Document

December 2019

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1.0. Background

STAP's paper on Novel Entities[1] identified six novel entities and technologies of relevance to the GEF including technological-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 these novel entities - blockchain technology, 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.

2.0. 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, based on an agreed consensus mechanism, and without a need for a trusted central authority.[2]

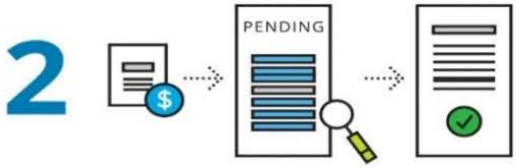
In a blockchain, data is grouped and organized into linked blocks with each block secured using cryptographic digital fingerprint called "hash[3]". Each "hash" points to the next block creating an unbroken chain of continuous data that can only be changed by modifying every block in the network, thus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

Blockchain has a number of unique features: 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.

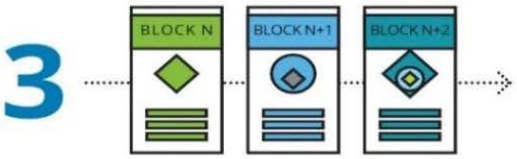
Blockchain technology has been widely used as: a system for the secure, transparent and immutable distributed storage of digital identities and records; a basis for digitally representing and tracking of real-world assets such as commodities, natural resources, ecosystem services, wastes etc., usually referred to as digital tokens[7]; and 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 permission 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.

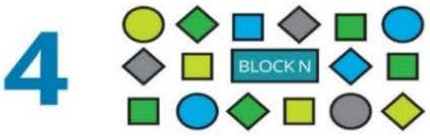
TRANSACTION Two parties exchange data; this could represent money, contracts, deeds, medical records, customer details, or any other asset that can be described in digital form.



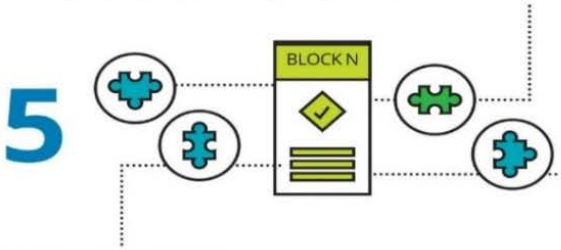
VERIFICATION Depending on the network's parameters, the transaction is either verified instantly or transcribed into a secured record and placed in a queue of pending transactions. In this case, nodes—the computers or servers in the network—determine if the transactions are valid based on a set of rules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



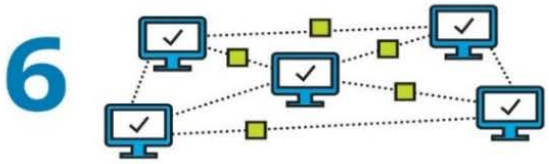
STRUCTURE Each block is identified by a hash, a 256-bit number, created using an algorithm agreed upon by the network. A block contains a header, a reference to the previous block's hash, and a group of transactions. The sequence of linked hashes creates a secure, interdependent chain.



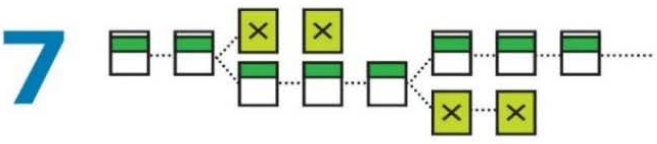
VALIDATION Blocks must first be validated to be added to the blockchain. The most accepted form of validation for open-source blockchains is proof of work—the solution to a mathematical puzzle derived from the block's header.



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 that the appropriate level of computing power was drained in solving.



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.



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]).

3.0. 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 secured 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, the Internet of Things (IoT) devices, Artificial Intelligence (AI), biometrics, smart meters, quick response (QR) code, and radio-frequency identification (RFID) chips.

Environmental applications of blockchain:

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

    - the Yale OpenLab Climate Project[11] aims to track the global carbon budget, monitor climate pledges and actions, and provides 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 following 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 which 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 production and supply chains of commodities. 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 behaviors 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 in Malawi who use sustainable farming methods to produce more tea without increasing the land take[18].

- ***Transforming the 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, and renewable energy generation) that individual or organizations can directly pay for to offset their environmental footprints. For example:

    - the CarbonX[19] and ClimateCoin[20] blockchain is a networking platform for individuals and companies to offset their carbon emissions and to create demand for their low-emission products and services.
    - the Nori blockchain-based 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 by paying 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 bio-piracy 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 an historical and immutable record of land and asset ownership[24]. Examples include the Bitland[25] and ChromaWay[26] blockchain 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] blockchain, which are using blockchain to track wastes, 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 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 data from GPS systems, passenger information, and journey tracking onto a blockchain platform to deliver real-time transport solutions in Malta[37].
    - in urban planning, city management and governance blockchain can lead to increased transparency and reduced bureaucracy[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 broadening 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 these are high risk. Blockchain may also help to 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.

4.0. 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 list (non-exhaustive) of existing and proposed blockchain uses. Figures 2a-i present the outcome of this mapping exercise. The figures show that there are several proposed and existing blockchain applications that 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 the weblinks to the examples of blockchain application in the figures.

Figure 2a: Biodiversity

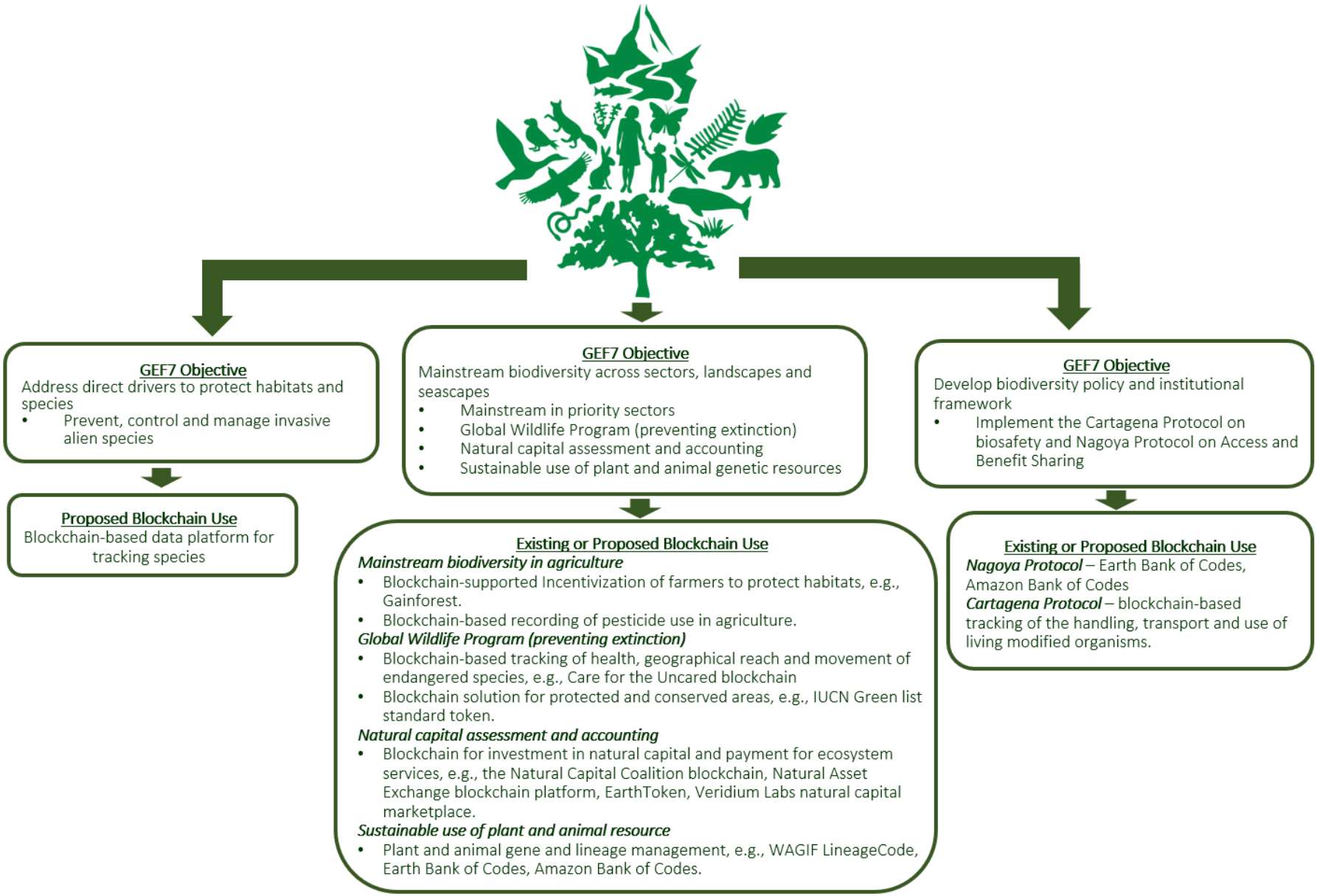


Figure 2b: Climate Change (Mitigation)

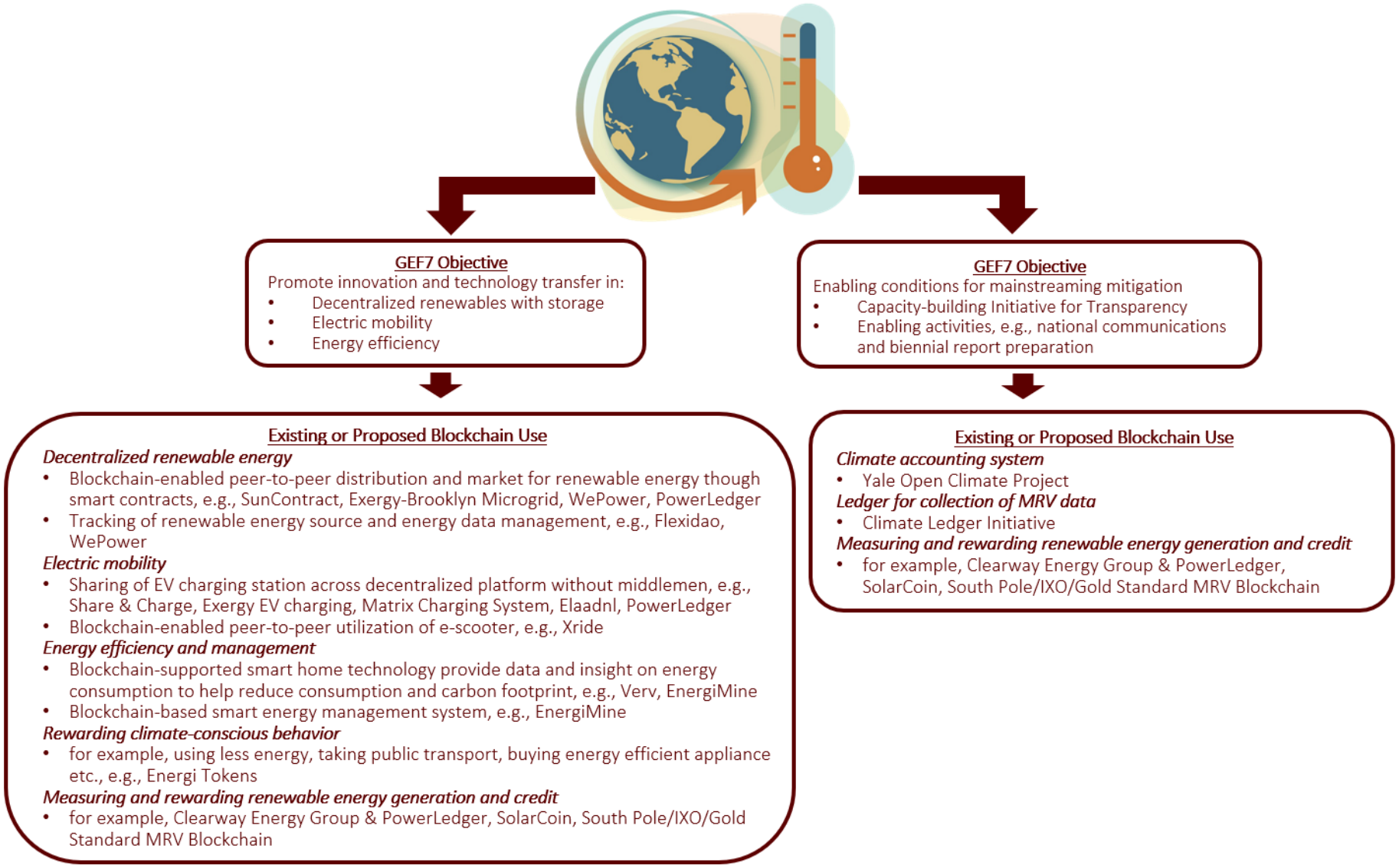
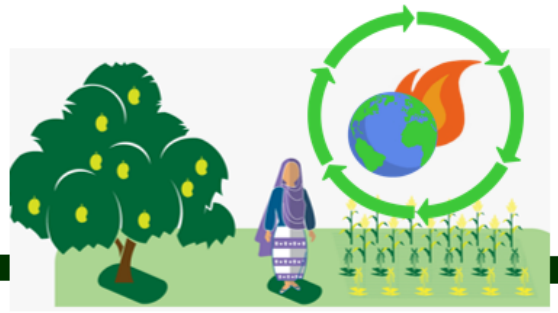


Figure 2c: Climate Change (Adaptation)



LDCF and SCCF Strategic Goal

To 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., Blockchain Climate Risk Crop Insurance, Aon/Etherisc/Oxfam Crop Insurance, and Worldcovr.

Strengthening resilience of the most vulnerable

- Blockchain-based identification and financial access for the unbanked and vulnerable, e.g., WFP Building Block 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.

Early warning and disaster resilience

- Blockchain-backed decentralized weather sensors for monitoring, forecast 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 mangrove 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 2d: Land Degradation

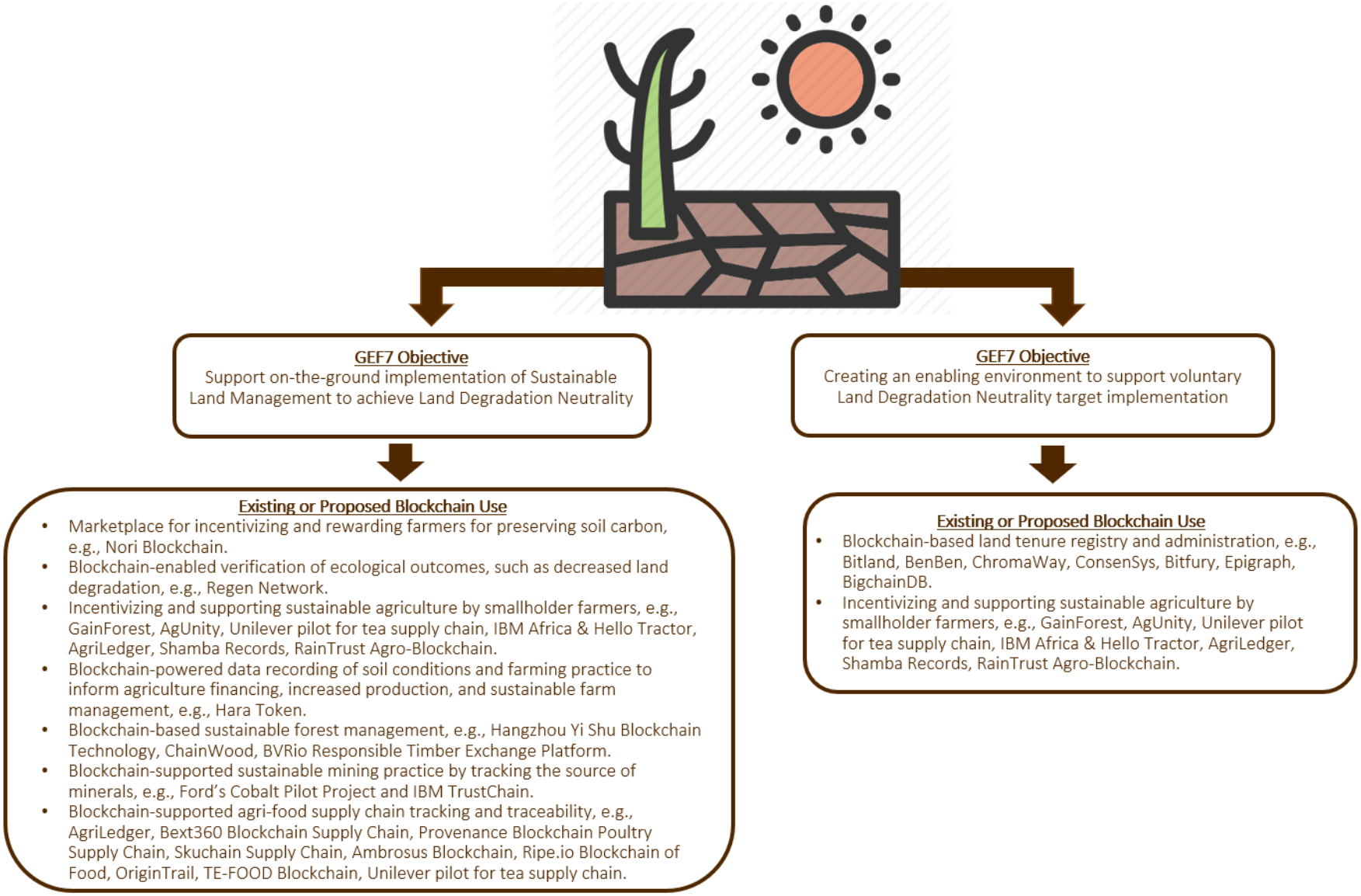


Figure 2e: International Waters

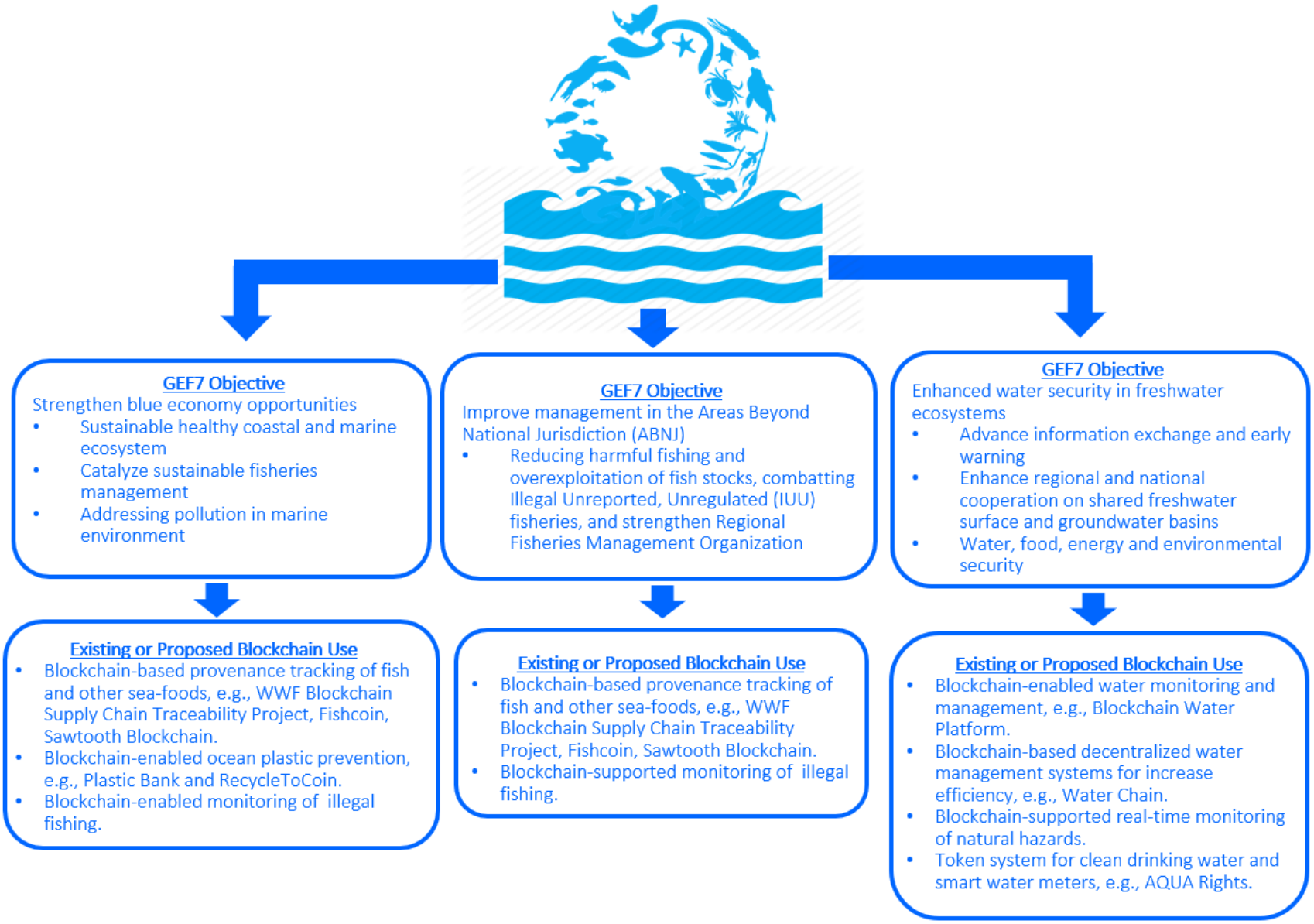


Figure 2f: Chemicals and Waste

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 Developing Countries** and **Small Island Developing States.**
- Support Conventions-related **Enabling Activities.**

Existing or Proposed Blockchain Use

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

Figure 2g: Food Systems, Land Use, and Restoration

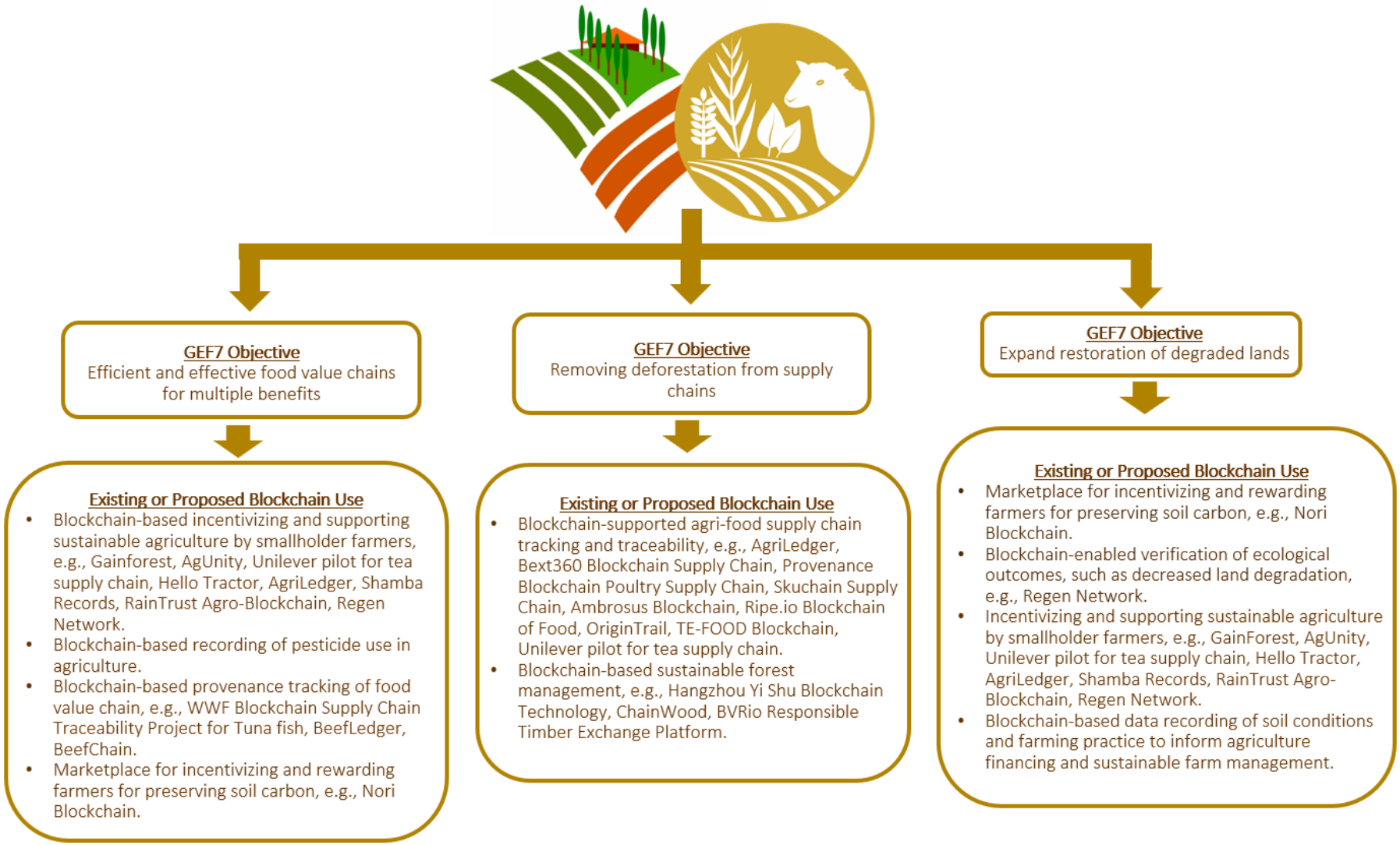


Figure 2h: Sustainable Cities

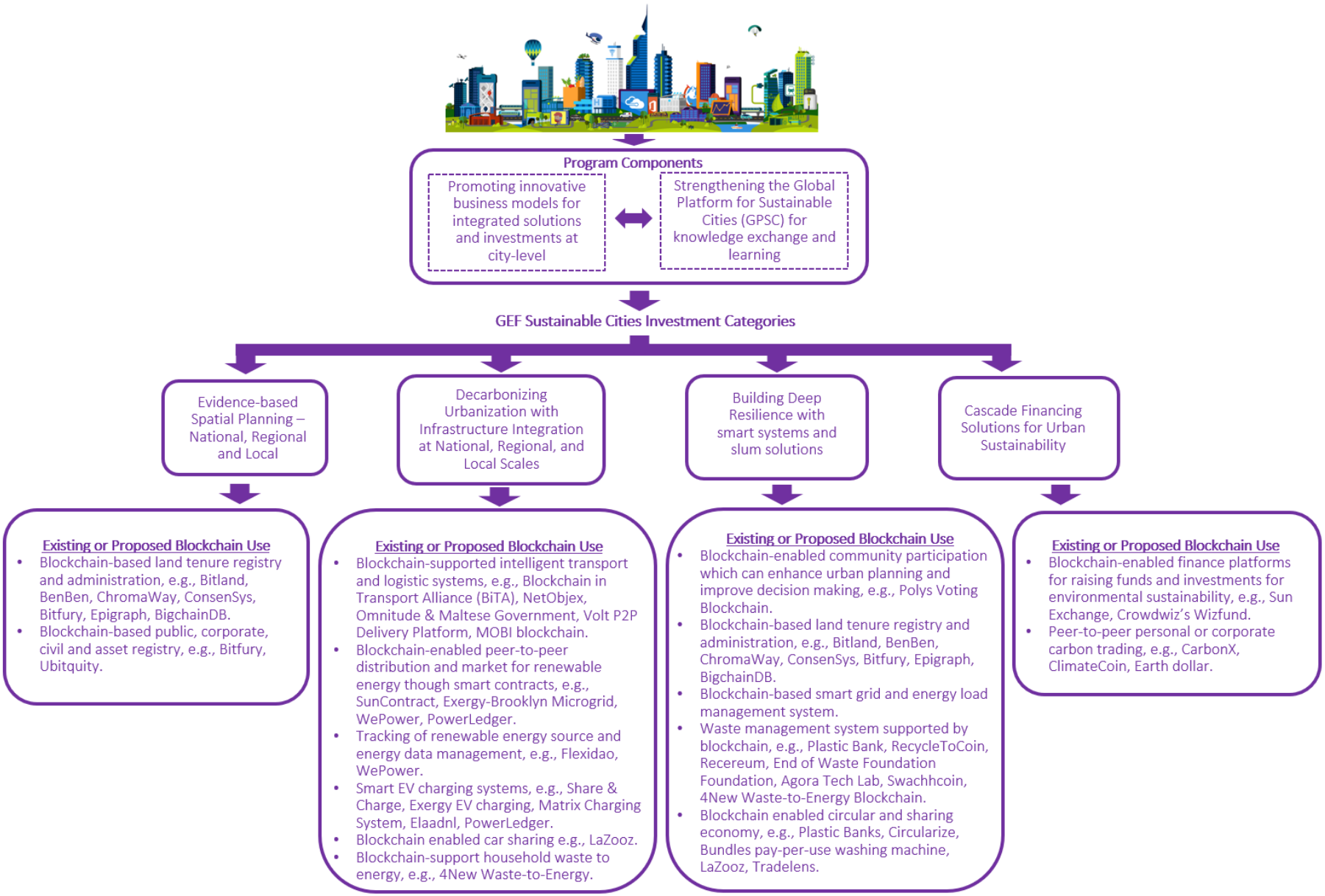
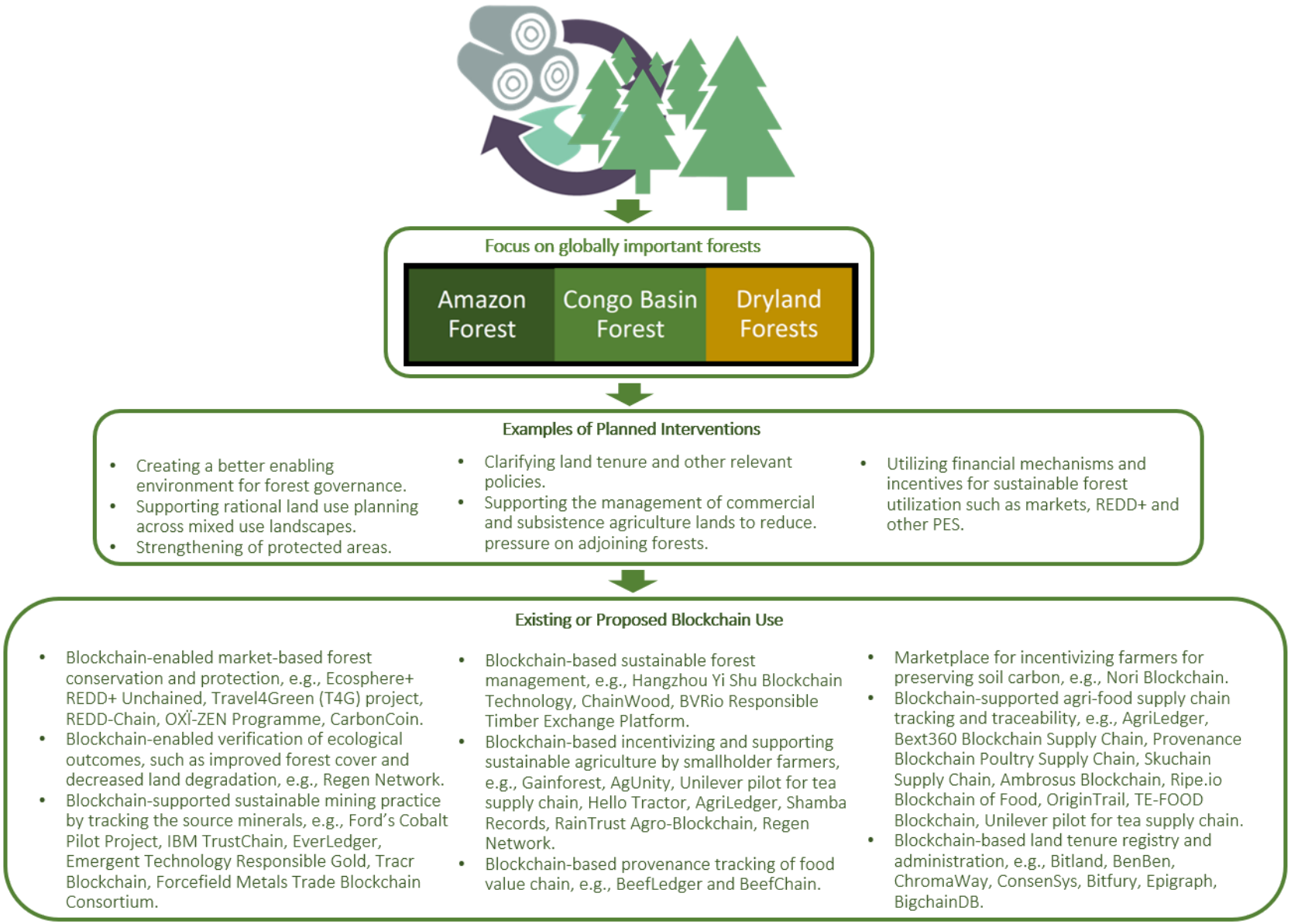


Figure 2i: Sustainable Forest Management



5.0. 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 of blockchain.*** The first blockchain systems, including Bitcoin, have large computational and energy requirements due to the algorithm used for consensus building[42]. Servers to power blockchain also use a range of metals. Newer blockchain systems are being developed which use less energy but the overall energy and material use should be considered when deciding whether to use blockchain.
- ***Data collection and security.*** Ideally collecting blockchain data should avoid 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 with limited access to these technologies.
- ***Lack of 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 may require 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. This may require investment in infrastructure or research to create low-cost alternatives suitable for developing countries[43].

In addition, other issues which may impede the adoption of blockchain are the lack of an agreed governance structure, and absence of standards and protocols.

6.0. 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.**

  There are some areas that seem particularly ripe for GEF to incorporate Blockchain. For example:
  - Track and verify sustainable charcoal production (land degradation focal area and Sustainable Forest Management Impact Program).
  - Reduce deforestation in agricultural systems by improving transparency in supply chains and incentivizing producers to implement more sustainable environmental practices (FOLUR Impact Program, land degradation, and biodiversity focal areas).
  - Improve the security and accuracy of land tenure systems (land degradation focal area, Sustainable Forest Management, FOLUR, and Sustainable Cities Impact Programs).
  - Improve water and energy resource management (climate change, international waters focal areas, and Sustainable Cities Impact Program).

- Improve energy access through a combination of decentralized renewable energy sources paired with microgrids, which can enable peer-to-peer markets and community trading (climate change focal area and Sustainable Cities Impact Program).
- Improve the traceability of energy sources which can allow differentiation between renewables and fossil fuels (climate change mitigation focal area).
- Decarbonize transportation systems (climate change focal area and Sustainable Cities Impact Program).
- Improve the traceability and tracking of chemicals supply chains (chemicals and waste focal area).
- Waste management and the circular economy (chemicals and waste focal area and 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 the cost, energy requirements, and 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 GEBs?
- 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 this be included in the project, or, if not, how would it be achieved?
- What are the possible unintended consequences, 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 programs and processes.**

  For example:

  - Consider existing internal GEF processes or programs to see if blockchain could improve record-keeping, transparency, trust, security, efficiency, and 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 if blockchain could be used to monitor the long-term durability of GEF projects.

- **Engage with existing initiatives which are developing environmental applications of blockchain.**

The GEF can leverage the works of existing initiatives and programs already working on blockchain applications for solving environmental challenges to create blockchain solutions for GEF-specific environmental challenges, or to access technical assistance for potential GEF projects which are considering blockchain. Some examples of these initiatives include:

- the Climate Chain Coalition[44], - a collaboration of diverse stakeholders aimed at using blockchain and other digital technologies to mobilize climate finance and improve measuring, reporting and verification of climate actions;
- the Yale Open Lab[45] - a collaboration aimed at creating 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 focus on using the technology to achieve the 2030 Agenda for Sustainable Development; and,
- The World Bank Group's Technology and Innovation Lab[48] which 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 more information on the listed examples of blockchain applications presented in Figures 2a-1 (in alphabetical order)

4New Waste-to-Energy Blockchain: https://www.the-blockchain.com/2018/07/16/4new-is-mining-crypto-with-waste-power/
Adaptation Ledger: https://www.adaptationledger.com/
Agora Tech Lab: https://www.agoratechlab.com/
AgriLedger: http://www.agriledger.io/
AgUnity: https://www.agunity.com/
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/plataforma/plataforma/madeira.do?language=en-us
CADENA Blockchain: https://blogs.iadb.org/integration-trade/en/blockchain-trade-safer/
CarbonCoin: https://carboncoin.cc/
CarbonX: https://www.carbonx.ca/
Care for the Uncared blockchain: 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/
Circularize: https://www.circularise.com/
Circulor Oracle Blockchain: https://www.oracle.com/uk/customers/circulor-1-blockchain.html
Clearway Energy Group & Power Ledger: https://www.powerledger.io/project/clearway-energy-group-united-states/
Climate Ledger Initiative: https://www.climateledger.org/
ClimateCoin: https://climatetrade.com/
ConsenSys: https://consensys.net/enterprise-ethereum/use-cases/realestate/
Crowdwiz Wizfund: https://crowdwiz.io/en
Earth Bank of Codes: https://www.earthbankofcodes.org/
Earth Dollar: https://earthdollar.org/home/
Earth Token: https://earth-token.com/
Ecosphere+ Redd+ Unchain: https://ecosphere.plus/
Elaadnl: https://www.elaad.nl/
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/en/
LaZooz: 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 Blockchain Platform: https://www.naturalasset.exchange/
NetObjex Transport: https://www.netobjex.com/use-cases/
Nori Blockchain: https://nori.com/
Omnitude & Maltese Government: https://omnitude.tech/omnitude-the-maltese-govt/
OriginTrail: https://origintrail.io/
OXI-ZEN Blockchain: https://www.oxi-zen.io/
Plastic Bank: https://plasticbank.com/
Polys Voting Blockchain: https://polys.me/
PowerLedger: https://www.powerledger.io/
Provenance Blockchain Poultry Supply Chain: https://www.provenance.org/case-studies/grass-roots
Provenance: https://www.provenance.org/
RainTrust Agro-Blockchain: https://raintrust.io/
Recereum: https://recereum.com/
RecycleToCoin: http://ww7.recycletocoin.com/
REDD-Chain: http://cleantech21.org/fileadmin/content/NBE/C21_H4C_REDD-Chain_Sum082018_v04.pdf
Regen Network Blockchain: 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
Sun Exchange: https://thesunexchange.com/
SunContract: https://suncontract.org/
Swachhcoin: http://www.swachhcoin.com/
TE-FOOD Blockchain: https://tefoodint.com/
The Natural Capital Coalition: https://naturalcapitalcoalition.org/the-natural-capital-blockchain-revolution/
Tracr blockchain: https://www.tracr.com/
Tradelens: https://www.tradelens.com/

Emergent Technology Responsible Gold: https://www.everledger.io/ **End of Waste Foundation:** https://endofwaste.com/#home **Energi Tokens:** https://www.energi.world/ **EnergiMine:** https://energimine.com/ **Epigraph:** http://epigraph.io/ **Etherisc:** https://etherisc.com/ **EthicHub:** https://ethichub.com/ **EverLedger**: https://www.everledger.io/ **Exergy EV charging:** https://lo3energy.com/ **Exergy**: https://exergy.energy/ **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/	**Travel4Green:** http://t4gpng.org/ **Ubitquity**: https://www.ubitquity.io/ **Unilever Tea Pilot:** https://www.greenbiz.com/article/unilever-teams-big-banks-blockchain-supply-chain **Veridium**: https://www.veridium.io/index.html **Verv:** https://verv.energy/ **Volt P2P Delivery Platform:** https://ico-tokensale.com/volt/ **WAGIF LineageCode:** https://www.lineagecode.com **WasteLedger:** http://www.wasteledger.com/ **Water Chain:** https://www.waterchain.io/ **Weatherblock:** http://www.weatherblock.org/ **WePower**: https://wepower.network/ **WFP Building Block Platform:** https://innovation.wfp.org/project/building-blocks **Worldcovr:** 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 Open Climate Project:** https://openlab.yale.edu/open-climate

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[3] A hash is a unique string of letters and numbers created from text using a mathematical formula

[4] OECD, 2019. OECD Blockchain Primer. http://www.oecd.org/finance/OECD-Blockchain-Primer.pdf

[5] 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 will need to change all the historical data on every single node.

[6] Hooper, M. 2018. Top five blockchain benefits transforming your industry. Blockchain Development. https://www.ibm.com/blogs/blockchain/2018/02/top-five-blockchain-benefits-transforming-your-industry/; Ray, S. 2018. The Difference Between Blockchains & Distributed Ledger Technology. https://towardsdatascience.com/the-difference-between-blockchains-distributed-ledger-technology-42715a0fa92; Nelson, P. 2018. Primer on Blockchain. USAID. https://www.usaid.gov/digital-development/digital-finance/blockchain-primer.

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[8] Smart contracts are digital protocol 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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